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THE DIFFERENCE OF THERMAL ENERGY TRANSMITTED TO THE EARTH BY RADIATION FROM DIFFERENT PARTS OF THE SOLAR SURFACE.

By Capt. J. ERICSSON.

From "Nature."

Perre Secchi, in the second edition of "Le Soleil," published at Paris, 1875, again calls attention to the result of his early investigations of the force of radiation emanating from different regions of the sun's surface, reiterating without modification his former opinions regarding the absorption of the radiant heat by the solar atmosphere. It will be well to bear in mind that the plan adopted by the Italian physicist in his original researches, on which his present opinion is based, was that of projecting the sun's image on a screen, and then, by means of thermopiles, measuring the temperature at different points. The serious defects inseparable from this method of measuring the intensity of the radiant heat I need not point out, nor will it be necessary to urge that a correct determination of the energy transmitted calls for direct observation of the temperature produced by the rays projected towards the earth. Accordingly, on taking up that branch of my investigations of radiant heat which relates to the difference of intensity transmitted from different parts of the sun's surface, I adopted the method of *direct* observation. The progress was slow at the beginning, owing to the necessity of constructing an astronomical apparatus of unusual dimensions, but having devised means which rendered the employment of any desirable focal length practicable, the work has progressed rapidly. An instrument of 17.7 metres (58 feet) focal length, erected to conduct preliminary experiments, has proved so satisfactory that the construction of one of 30 metres focal length, which I supposed to be necessary, has been dispensed with. Considering that the apparent diameter of the sun at a distance of 17.7 metre's from the observer's eye is 162.4 millimetres even when the earth is in aphelion, the efficacy of the instrument employed might have been anticipated. The nature of the device will be readily comprehended by the following explanation :—Suppose a telescopic tube 17.7 metres long, 1 metre in diameter, devoid of object-glass and lenses, and mounted equatorially, to be closed at both ends by metallic plates or diaphragms, at right angles to the telescopic axis. Suppose the diaphragm at the upper end to be perforated with two circular apertures 200 millimetres in diameter, situated one above the other in the vertical line, 360

millimetres from centre to centre; and suppose a third circular perforation whose area is one-fifth of the apparent area of the solar disc, viz. 72.6 millimetres diameter, to be made on either side of the vertical line. Suppose, lastly, that the diaphragm which closes the lower end of the tube be perforated with three small apertures 6 millimetres in diameter, whose centres correspond exactly with the centres of the three large perforations in the upper diaphragm. The tube being then directed towards the sun, and the actinometers applied below the three small apertures in the lower diaphragm, it will be evident that two of these instruments will, after due exposure to a clear sun, indicate maximum solar intensity, say 35° C., while the actinometer applied in line with the perforation whose area is one-fifth of the apparent area of the solar disc, will indicate $\frac{35}{5}=7°$ C., unless the central portion of the solar disc radiates more powerfully towards the earth than the rest, in which case a higher intensity than 7° C. will be indicated by the actinometer referred to. It will be readily understood that the solar rays entering through the perforations at the upper end of the tube, converge at the lower end and pass through the small perforations, causing maximum indication of the focal actinometers as stated. Now, suppose that a circular plate, the area of which is exactly four-fifth of the apparent area of the sun, viz. 145.2 millimetres diameter, be inserted concentrically in either of the two large perforations of the diaphragm at the top of the telescopic tube. The apparent diameter of the sun being as before stated 162.4 millimetres, it will be perceived that the inserted plate will only partially exclude the solar radiation, and that the rays from a zone 1′ 42″ wide will pass outside the said plate, converging in the form of a hollow cone at the lower end of the tube, and there enter the respective actinometer. The indication of the latter will then show the thermal energy transmitted by radiation from a zone whose mean width extends 49″ from the sun's border. It should be particularly observed that the three focal actinometers employed will be acted upon *simultaneously* by the converged rays, (1) from the entire area of the solar disc, (2) from a *central* region containing one-fifth of the area, and (3) from a *zone* at the border containing also one-fifth of the area of the solar disc. It is scarcely necessary to point out that an accurate comparison of the intensity of the radiant heat emanating from the central part and from the sun's border calls for *simultaneous* observation, in order to avoid the errors resulting from change of zenith distance and variation of atmospheric absorption during the investigation. The great advantage of obtaining also a simultaneous indication of the intensity transmitted by radiation from the entire solar disc is self-evident, since this indication serves as an effectual check on the observed intensities emanating from the *centre* and from the *border*. The latter obviously must be less, while the former must be greater, for a given area, than the indication of the focal actinometer which receives the radiation of the entire solar disc.

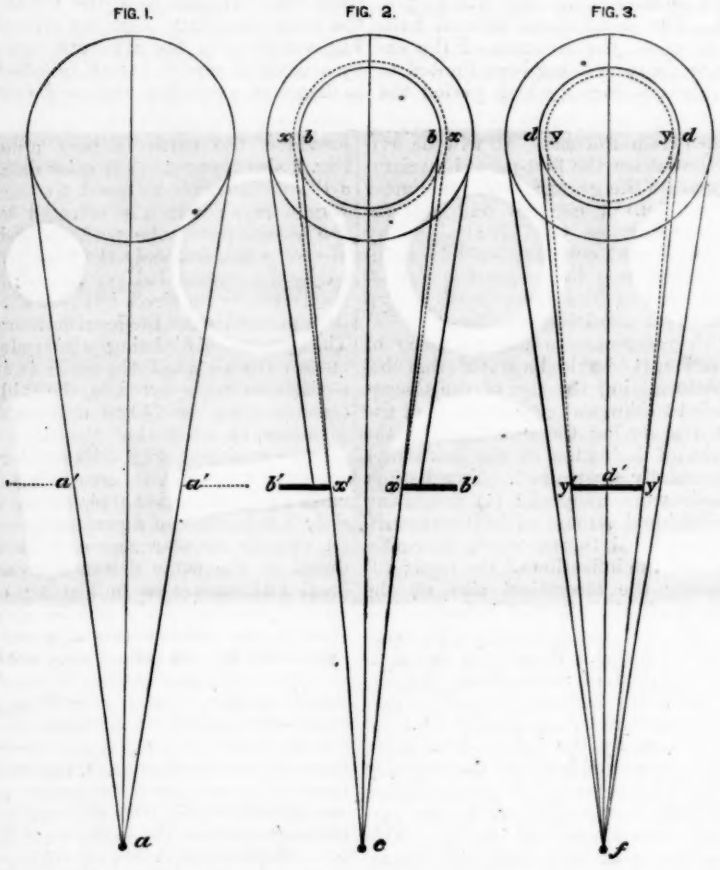
The foregoing demonstration, based on hypothesis, having established the possibility of ascertaining by direct observation the temperature produced by the rays projected from certain parts of the solar surface, let us now examine the means actually employed. An observer on the 40th deg. latitude, stationed on the north side of a building 28 metres high pointing east and west, can just see the sun pass the meridian, during the summer solstice, if he occupies a position about 8 metres from such building. Now, if an opaque screen perforated by a circular opening 313 millimetres in diameter be placed on the top of the supposed building, the entire solar disc may be seen through the same, provided it faces the sun at right angles. But if perforation in the said screen be 140 millimetres in diameter, only one-fifth of the area of the solar disc will be seen. And if the screen be removed and a circular plate 280 millimetres in diameter put in its place, the observer, ranging himself in line with the plate and the sun's centre, can only see a narrow border 1′ 42″ of the solar disc. Obviously the screen placed on the top of the building might be perforated like the upper diaphragm of the supposed telescopic tube, and a plate resembling the lower diaphragm, secured by appropriate

means near the ground, might be made to support the focal actinometers in such a manner that their axes pass through the centres of the perforations of the screen above the building. It is hardly necessary to state that the plate supporting the actinometers should be attached to some mechanism capable of imparting to it a parallactic movement, during the observation, corresponding with the sun's declination and the earth's diurnal motion; and, that some adequate mechanism should be employed for regulating the position of the perforated screen and adjusting the focal distance in accordance with the change of the subtended angle consequent on the varying distance from the sun. It will be evident that since the first-named mechanism rests on the ground, while the latter is secured to a massive building, far greater steadiness will be attained by our simple and comparatively inexpensive device, than by employing a telescopic tube of the most perfect construction mounted equatorially.

With reference to the influence of diffraction, it should be stated that before determining the size of the screens intended to shut out certain parts of the solar disc during the investigation, the amount of inflection of the sun's rays was carefully ascertained. Two distinct methods were adopted: (1) measuring the additional amount of heat transmitted to the focal thermometers in consequence of the inflection of the rays; (2) increasing the *theoretical* size of the screens until the effect of inflection was overcome and the luminous rays completely excluded. Regarding the first-named method of ascertaining the diffraction, it is important to mention that the temperature transmitted to the focal actinometers by the inflected radiation which passes outside of the theoretically determined screens is not proportionate to the inflection ascertained by the process of enlargement referred to. This circumstance at first rendered the investigation somewhat complicated, but it soon became evident that the discrepancy is caused by the comparatively small inflection of the *invisible* heat rays. It will be seen presently that the radiant heat which passes outside of the screens in consequence of diffraction is considerably less than that which would be transmitted to the focal actinometers if the calorific rays were subjected to an amount of inflection corresponding with the enlargement of the screens beyond the theoretical dimensions necessary to exclude the luminous rays.

Let us first consider the method of ascertaining the inflection of the rays by measuring the additional amount of heat transmitted to the focal actinometers. Fig. 1, see illustration, represents the solar disc, a being the focal actinometer exposed to the converged rays, $a'\,a'$ representing an imaginary plane situated 17.7 metres from a, at which distance the section of the pencil of converging rays will be 162.4 millimetres in diameter, provided the earth is near aphelion. Fig. 2 also represents the solar disc, and c the actinometer exposed to the converged rays; but a perforated screen $b'\,b'$ is interposed, the perforation being of such a size that only the rays projected by the central half of the solar disc (indicated by the circle $b\,b$) pass through the same and reach the focal actinometer. The screen $b'\,b'$ being situated 17.7 metres from c when the earth is in the position before referred to, the said perforation must be 114.83 millimetres in diameter, in order that the lines $b\,x'\,c$ may be straight. Fig. 3 likewise represents the solar disc, its area being divided in two concentric halves by the circle $d\,d$; but in place of a perforated screen, an opaque circular screen d' is introduced at the same distance from the focal actinometer as in Fig. 2; consequently the lines $d\,y'\,f$ will be straight. Now, if the actinometers a, c *and* f be exposed to the converged solar radiation *simultaneously and during an equal interval of time*, c and f receiving the heat from one half of the solar disc (the former from the central and the latter from the surrounding half), the temperatures of c and f added together should correspond exactly with the temperature transmitted from the entire solar disc to a. Observation, however, shows that the temperatures of c and f together is 0.091 greater than the temperature imparted to a. Hence an increase of temperature of nearly one-eleventh is produced by the inflection of the calorific rays, one-half being the result of the bending of the rays within the perforation of the screen $b'\,b'$, the other half re-

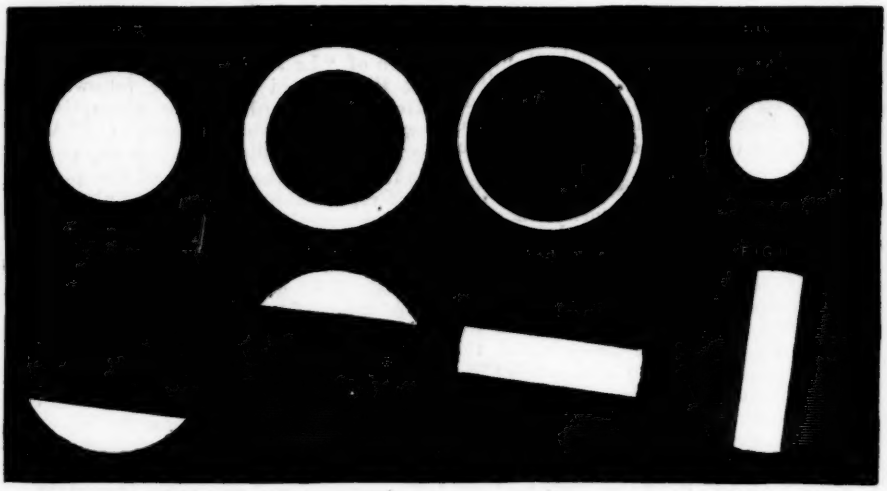
sulting from the bending outside of the screen d'. The increment of temperature being thus known, the degree of inflection may be easily determined by drawing a circle $x\,x$ round the circle $b\,b$, covering an additional area of $\frac{0.091}{2}$ $=0.0455$; and by inscribing a circle $y\,y$ within $d\,d$, covering an area of 0.0455 less than the area of $d\,d$. It will be perceived on reflection that $x\,x'\,b$ represents the angle of inflection of the calorific rays within the perforation of the screen $b'\,b'$, and $d\,y, y$ represents the angle of inflection outside of the screen d'. Demonstration shows that the former angle



measures 14″.57, while the latter measures 14″.86, the mean being 14″.71. Having thus determined the inflection resulting from invisible radiation, let us now ascertain the inflection of the luminous rays. As before stated, the apparent diameter of the sun at a distance of 17.7 metres from a given point is 162.4 millimetres when the luminary is furthest from the earth. Now our investigation shows that a screen 167 millimetres in diameter hardly suffices to exclude the luminous rays; hence their inflection amounts to $\frac{167-162.4}{2}=2.3$ millimetres in a distance of 17.7 metres.

Their angle of inflection will therefore be 26″.81, against 14″.71 for the dark rays. We have thus incidentally established the fact that the inflection of the luminous and calorific rays differs nearly in the same proportion as the calorific energies of the visible and invisible portions of the solar spectrum.

Our space not admitting of a detailed account of the result of the investigation, the leading points only will be presented. The observations have all been made at noon, the duration of the exposure to the sun having been limited to seven minutes, during which period the actinometers are moved, by the parallactic mechanism, through a distance of 55 centimetres, from west to east. The intensity of the radiant heat imparted to the actinometers has been recorded by the observers at the termination of the fourth, fifth, sixth and seventh minute, the exact moment for reading off being indicated by a chronograph. The relative intensities transmitted by radiation from the centre and from the border of the solar disc, first claim our attention. Fig. 6 represents the solar disc covered by a circular screen 145.25 millimetres in diameter, excluding the rays except-



ing from a narrow zone, the mean width of which is situated 49″ from the border of the photosphere. Fig. 7 shows a screen excluding the solar rays excepting from the central portion, *the area of which is precisely equal to the area of the narrow zone* in Fig. 6. The following table shows the intensities transmitted to the actinometers during an observation, August 25, 1875, the radiation from the solar disc being then excluded in the manner shown in Figs. 6 and 7 :

Time.	Central portion. Cent.	Border. Cent.	Rate of difference.
4′	3°.28	2°.19	$\frac{2.19}{3.28}=0.667$
5′	3°.56	2°.37	$\frac{2.37}{3.56}=0.665$
6′	3°.73	2°.49	$\frac{2.49}{3.73}=0.667$
7′	3°.88	2°.60	$\frac{2.60}{3.88}=0.669$
			Mean=0.667

It should be particularly observed that this table records the result of four distinct observations ; nor should it be overlooked that although the intensities vary greatly for each observation in consequence of the continued exposure to the sun, yet the rates showing the difference of the intensity of the rays transmitted from the border, inserted in the last column, is practically the same for each observation, the discrepancy between the highest and the lowest rate

being only 0.004.* Persons practically acquainted with the difficulty of ascertaining the intensity of solar radiation will be surprised at the exactness and consistency of the indications of our actinometers. This desirable exactness has been attained by surrounding the actinometers with water-jackets, which communicate with each other by connecting pipes, through which a steady stream of water is circulated. By this expedient the chambers containing the bulbs of the several thermometers are maintained with critical nicety at equal temperature, an inexorable condition when the object is to determine differential temperature with great exactness. Apart from this, the chambers which contain the bulbs of the thermometers are air-tight, the radiant heat being admitted through a small aperture at the top of the chamber, covered by a thin crystal.

Referring to the preceding table, it will be seen that the intensity transmitted by radiation from the sun's border, represented in Fig. 6, is 0.667 of the intensity transmitted from the central region represented in Fig. 7, the area of each being precisely alike. From the stated intensity must be deducted the heat imparted to the actinometer by the inflection of the calorific rays. The circumference of the perforation of the screen shown in Fig. 7 being exactly one-half of the circumference of the screen in Fig. 6, while the central region radiates more powerfully than the border, fully one-half of the inflected radiation from the border will be balanced by the inflected radiation emanating from the central region. Agreeable to the previous demonstration relating to Figs. 2 and 3, it will be seen that the unbalanced inflection amounts to 0.029; hence the radiation transmitted from the border zone will be $0.667 - 0.029 = 0.638$ of the intensity of radiation transmitted from the central region. We have thus shown by a reliable method that the intensity of the rays directed towards the earth from the border zone suffers a diminution of $1.000 - 0.638 = 0.362$ of the intensity of the radiation emanating from the central region. But the mean depth of the solar atmosphere of the border zone, in the direction of the earth, is 2.551 greater than the vertical depth, while the mean depth over the central region referred to is only 0.036 greater than the vertical depth of the solar atmosphere. Consequently, if we accept the assumption that the retardation is as the depth, the absorption by the solar atmosphere cannot exceed $\frac{0.362}{2.551-0.036} = 0.144$ of the radiant heat emanating from the photosphere.* It will be found on referring to the revised edition of "Le Soleil," vol. i., page 212, that Père Secchi makes the following statements regarding the absorptive power of the solar atmosphere. (1) "At the centre of the disc, that is to say perpendicularly to the surface of the photosphere, the absorption arrests about $\frac{2}{3}$ or more exactly $\frac{66}{100}$ of the total force." (2) "The total action of the absorbing envelope on the hemisphere visible from the sun is so great that it allows only $\frac{12}{100}$ of the total radiation to pass, the remainder, namely, $\frac{88}{100}$ being absorbed." It is unnecessary to criticise these figures presented by the Roman astronomer, as a cursory inspection of our table and diagrams is sufficient to show the fallacy of his computations. Apart from determining the absorptive power of the solar atmosphere, the most important problem which may be solved by accurately measuring the intensity of the radiation emanating from various parts of the disc, is that relating to the sun's emissive power in different directions. In order to decide this question, I have adopted the plan of measuring the energy of the radiant heat transmitted from zones crossing the solar disc at right angles, as shown in Figs. 10 and 11. Should it be found that our actinometers are equally affected by the radiation from these zones, each of which occupies an arc of 30 deg. containing one-third of the area of the disc, the inference will be irresistible that the sun

* All my instruments for measuring radiant heat have been graduated to the Fahrenheit scale, which practically is more exact than the Centigrade, owing to its finer divisions. For the benefit of the Continental readers of *Nature*, and in order to satisfy English and American advocates of the course Centigrade, the observed temperatures have been reduced to that scale before being entered in our tables.

* In the first edition of "Le Soleil," p. 264, the author assumes that the absorption of the calorific rays by the atmosphere "augments in proportion to the secant of the zenith distance;" in other words, as the depth of the atmosphere penetrated from the rays.

emits heat of equal intensity in all directions. It should be borne in mind that, agreeable to our method, the radiations from these zones are observed simultaneously. The arrangement exhibited in Figs. 10 and 11 hardly needs explanation. Referring to Fig. 10, it will be seen that two segmental screens are employed excluding the radiant heat, excepting from the zone, which is parallel with the sun's equator. Similar screens are employed (see Fig. 11) for excluding the rays excepting from the zone parallel with the sun's polar axis. The curvatures of the segmental screens, it should be observed, have been struck to a radius of ninety millimetres, in order to cut off effectually the inflected radiation from the sun's border. Obviously diffraction has not called for any correction of our observations relating to this part of the investigation, since the inflected radiation from the equatorial zone exactly balances the inflected radiation from the polar zone. It only remains to be stated that repeated observations show that the radiant energies transmitted to the actinometers from the two zones are identical. The result of observations relating to the radiation emanating from the polar regions, represented in Figs. 8 and 9, together with other observations, will be discussed in future communications.

ARCS OF ADJUSTMENT—FOR FLATTENING THE EXTREMITIES OF RAILROAD CURVES.

By Mr. N. B. PUTNAM.

Written for Van Nostrand's Engineering Magazine.

A railway car moving on a curve is, at every point of its path, acted upon by a normal force, which tends to drive the car from the rails and away from the centre. This force, called centrifugal force, is $\frac{m v^2}{r}$ Gaussian pound units, and is equal to the weight of $\frac{m v^2}{g r}$ lbs., m being the mass of the car; v its velocity in feet per second; r the radius of curvature of the path, at any given point, in feet; and $g=32.2$ the numerical value of the force of gravity on unit mass. This force bears to the weight of the car the proportion of $\frac{v^2}{g r} : 1$; and this is the ratio which the elevation of the outer rail at the given point, or cant must bear to the gauge, in order that the action of gravity in forcing the car down the inclined plane shall equal and oppose centrifugal force.

In circular curves r is constant, and consequently

$$\text{cant} = \text{gauge} \times \frac{v^2}{32.2\, r}$$

is constant throughout the whole extent of the curve. When the velocity is given in miles per hour $=$ V, $v = \frac{5280}{3600}$ V and cant $=$ gauge $\times \frac{\text{V}}{15\, r}$ nearly.

As it is impossible to adjust the cant for all speeds, it is customary to adopt the highest ordinary velocity for the value of V.

Let V $=40$, and let $4'.7$ be the gauge, then cant $= 4.7 \frac{1600}{15\, r} = \frac{500}{r}$ nearly.

In circular curves $r = \frac{100}{\text{Sin D}^\circ} = \frac{100}{\text{D sin}1^\circ}$

$\therefore$ cant $= 5$. D. sin $1^\circ = .088$ D nearly, in which D is the degree of the curve. Thus the cant for V $=40$ is about $1''$ per degree of curve on a $4'\ 8\frac{1}{2}''$ gauge.

With V constant cant $\propto \frac{1}{r}$, and in order that the formula may hold good for all parts of a curve, every change of cant should be accompanied by a change of curvature, and since changes of cant must be gradual, changes of curvature should be gradual also. The simplest law in accordance with which we should desire the cant to vary, is that the cant at different points should be proportional to the distance of these points from the beginning of the curve; in other

words, the level of the outer rail should change by a uniform gradient; then in passing from a straight line where the value of cant is zero, to a circular curve or radius r, where the cant is c, the straight line and circle should be connected by a curve tangent to, both which commences with an infinite radius of curvature or curvature$=o$, which terminate with a radius of curvature$=r$, and which at any intermediate point has a curvature directly or a radius of curvature inversely proportional to the distance of the point from the commencement of the curve.

Froude's "curve of adjustment" is a close approximation to such a curve. According to Mr. Froude, the length of the curve of adjustment should be not less than 300 feet for every foot of change of cant.

Taking the gradient of the outer rail as 1 : 300, and applying this curve to circles of 1, 1½, 2 degrees, we have for shift 0.005, 0.017, 0.04 ft.

The value for shift varying as D³.

[See Rankine's Civil Engineering, p. 642, eqs. (6) and (7).]

Thus the shift for a 2° curve is less than ½ inch, and the tangent, curve of adjustment and circular curve, practically coincide with the tangent and original curve.

We assume then that, in the transition from a tangent line to a curve, whose degree is not greater than 2 or from a D' curve to a D'' curve where $D \sim D' \leq 2$, the change of cant may be "humored in" with a degree of accuracy sufficient for railroad work.

Let A A A′ (Fig. 1) be a circular rail-

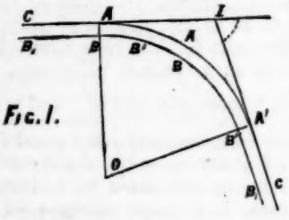


Fig. 1.

road curve, of radius R, connecting the tangent lines C A I, I A′ C, A and A′ being the tangent points; the common distance of these points from I is

$$AI = A'I = R \tan \tfrac{1}{2} I.$$

Let B B B′ be a curve parallel to A A A′, and at a distance A B from it; B, B, B′ B, the tangents to B B B′ at B and B′ are then parallel to C A and C A′ respectively.

A B is called the shift of the curve A A A′ or "the shift," and B B B′, the shifted curve. B, B, B′ B, are called auxiliary tangents.

When the radius of the curve B B B′ is given and the shift is known, $AI = (r+s) \tan \frac{1}{2} I = A'I$ in which r=radius of B B B′ and s=A B.

The object of the following problems is to connect a tangent line C A and a shifted curve B B B′ by means of a circular arc or a number of arcs of equal length, such that the difference of degree of the adjacent arcs shall be constant and shall not exceed 2,—the tangent line being considered a 0° curve,—and also to deduce the relation between the length of an arc of adjustment and the shift A B.

Problem I.—To find the length 'a' of a single arc of adjustment of radius $2r$, which shall connect a tangent line A C and a circular curve B B B′ of radius r, on which a cant c is due; the shift being A B$=s$.

The value of cant on the arc of adjustment is $\frac{1}{2}c$; then in passing from the tangent to the curve there will be two changes of cant each being $\frac{1}{2}c$.

Consider for the time the length a as known, and let B B′$=\frac{1}{2}a$ (Fig. 2).

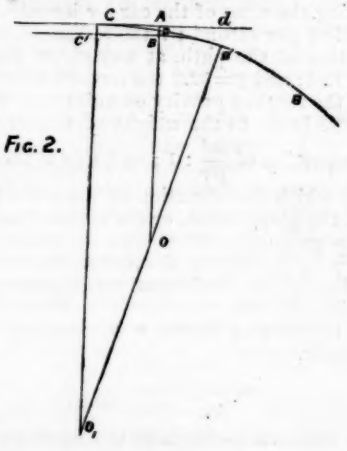


Fig. 2.

Draw B′ o and produce it until B′ o_1 = 2 B′ o = 2 r, with o_1 as centre and o_1 B′ as radius, describe an arc B′ C = a, tangent to B B′ B at B′, C B′ will then be tangent to C A at C. For the angle at o_1 is equal to the angle at o, and consequently the tangent to C B′ at C coincides with or is parallel to C A, but by hypothesis the length 'a' is sufficient to connect the tangent line and curve, therefore C B′ is tangent to C A.

To find 'a':

Bisect the curve C B′, its middle point D will be on the line A B. The tangent deflection for a chord 'a' of a circle of radius r, represented by *t. d.* (r. a), is $\frac{a^2}{2r} = T$; then

$$A D = t.\ d.\ (2r.\ \tfrac{1}{2}a) = \tfrac{1}{8}\frac{a^2}{2r} = \tfrac{1}{8}T$$

$$B D = t.\ d.\ (r.\ \tfrac{1}{2}a) - t.\ d.\ (2r.\ \tfrac{1}{2}a) = \tfrac{1}{8}T$$

$$\therefore\ s = A B = \tfrac{1}{4}T = \frac{a^2}{8r}$$

Whence $a = \sqrt{8\,r.\,s.}$

When a is given

$$s = \tfrac{1}{4}\ t.\ d.\ (r.\ a) = t.\ d.\ (r.\ \tfrac{1}{2}a).$$

The following statements made in this, and similar statements made in subsequent problems, are not mathematically accurate; that D the middle point of C B′ is on the line A B; that B D = *t. d.* (r. $\frac{1}{2}a$) − *t. d.* (2 r. $\frac{1}{2}a$); that chord C D = arc C D = $\frac{1}{2}a$; the errors, arising from regarding such statements as true, are, however, too small to be regarded in railroad curves.

To lay out the curve of *Prob. I.*, a and s being known. For D the middle point of C B′, bisect A B; for C, measure back on the tangent line, from A, a distance A C = $\sqrt{\frac{1}{4}a^2 - \frac{1}{4}s^2} = \frac{1}{2}a$; for B′ measure, forward from A along the tangent line, a distance A d = $\sqrt{\frac{1}{4}a^2 - s^2}$, and at d lay out an offset whose length is s + *t. d.* (r. $\frac{1}{2}a$) = 2 s. If the curve B B′ B be laid out from the auxiliary tangent C′ B, the position of B′ may be found by the sub-deflection angle for sub-chord $\frac{1}{2}a$; its value is

$$d' = \frac{a}{400}\,D$$

in which D is the degree of the curve.

Problem II.—To find the length 2 a of a curve of adjustment, composed of two circular arcs of equal length of radii 3 r and $\frac{3}{2}r$, which shall connect a tangent line A c and a circular curve B B′ B of radius r, on which a cant c is due; the shift being A B = s (Fig 3).

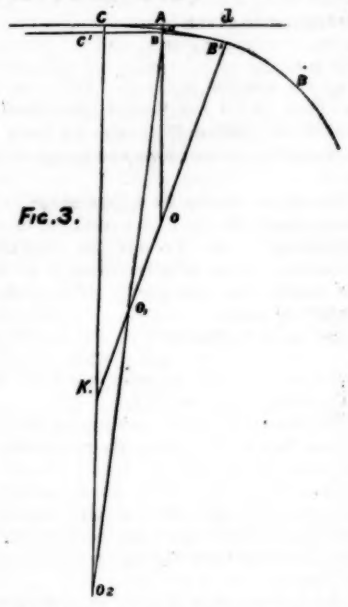


Fig. 3.

The values of cant are $\frac{1}{8}c$ c, $\frac{3}{8}c$, so that in passing from the tangent to the curve there will be three changes of cant each of $\frac{1}{8}c$.

Consider 2 a as known, and let B B′ = a, draw the radius B′ 0 and produce it until B′ 0_1 = $\frac{3}{2}$ B′ o = $\frac{3}{2}r$; with o_1 as centre and B′ o_1 as radius describe an arc B′ D = a; draw D o_1 and produce it until D o_2 = 3 r; with o_2 as centre and D o_2 as radius describe an arc D c = a; then will C D B′ be tangent to C A at C. For draw the radius C o_2 and produce B′ o until it intersects it in R, then ∠ C R B′ = ∠ o_2 + ∠ o_1 = ∠ B o B′, consequently B o and c o_2 are parallel, and the tangent to C D B′ at C coincides with A C, since the length 2 a is sufficient to connect the tangent line and curve.

To find 'a':

Bisect C B′ in D; it will be on the line A B.

$$A D = t.\ d.\ (3r.\ a) = \tfrac{1}{8}T.$$

$B D = t.d.\ (r.a) - t.d.\ (\frac{2}{3} r.a) = T - \frac{2}{3} T = \frac{1}{3} T.$

$\therefore \quad s = A B = \frac{2}{3} T = \frac{1}{3} \frac{a^2}{r}$

Whence $a = \sqrt{3 r s} \quad 2a = \sqrt{12 r s}$

When a is given

$$s = \frac{2}{3} t.d.\ (r.a).$$

To lay out the curve of *Prob. II.*; for D, bisect A B; for c measure back on the tangent line $A c = \sqrt{a^2 - \frac{1}{4} s^2} = a$; for B′, measure forward on the tangent line $A d = \sqrt{a^2 - \frac{3}{4} s^2} = \sqrt{a^2 - T^2}$, and at d measure an offset $= \frac{1}{3} t.d.(r.a) = \frac{1}{3} s$; or for B′ measure along c'B produced, a distance = A d and lay out an offet $= \frac{1}{12} s$. When the curve B B′B is laid out from the auxiliary tangent c'B, B′ may be located by a sub-deflection angle as in *Prob. I.* its value is

$$d' = \frac{a}{200} D.$$

Problem III.—To find the length $3a$ of a curve of adjustment, composed of three circular arcs of equal length, of radii $4r$, $2r$, $\frac{3}{2} r$, which shall connect a tangent line A C and a circular curve B B′B of radius r, on which a cant c is due, A B = shift = s (Fig. 4). The values of cant are $\frac{1}{4} c$, $\frac{1}{2} c$, $\frac{3}{4} c$, c.

As before, consider 'a' as known; let $B b = \frac{1}{2} a$ (Fig. 4), and $B B' = \frac{3}{2} a$, then $\angle B o B' = \frac{3}{2} B o B'$. Draw B′ o and produce it until $B' o_1 = \frac{3}{2} B' o = \frac{3}{2} r$, with o_1 as centre and o_1 B′ as radius, describe an arc B′ D′ $= a$; draw D′ o_1 and produce it until D′ $o_2 = 2r$, with o_2 as centre and D′ o_2 as radius describe an arc D′ D″ $= a$; draw D″ o_2 and produce it until D″ $o_3 = 4r$, with o_3 as centre and D″ o_3 as radius describe an arc D″ $c = a$; then will B′ D′ D″ c be tangent to cA at c.

For draw $c\,o_3$ and produce B′o until it intersects $c\,o_3$ in K; $\angle$ C K B′ $= \angle o_3 + \angle o_2 + \angle o_1 = \frac{3}{2} b o B' = B o B'$, consequently c 0 and B 0 are parallel and c B′ (as in *Problems I.* and *II.*) tangent to c A at c.

To find 'a':

Produce the arc C D″ (Fig. 4 A) until C $D_1 = \frac{3}{2} a$ and the arc B′ D′ until B′ $D_2 = \frac{3}{2} a$, and bisect CD″D′B′ in D. D_1, $D_1 D_2$ may be considered as points in the straight line A B; then A B = A D_1 + D_1 D + D D_2 + D_2 B. Let $T = t.d.\ (r.a)$.

$$A D_1 = t.d.\ (4 r. \frac{3}{2} a) = \frac{9}{16} T$$

$D_1 D = t.d.\ (2 r \frac{1}{2} a) - t.d.\ (4 r. \frac{1}{2} a) = \frac{1}{8} T - \frac{1}{16} T = \frac{1}{16} T.$

$\therefore \quad A D = \frac{5}{8} T.$

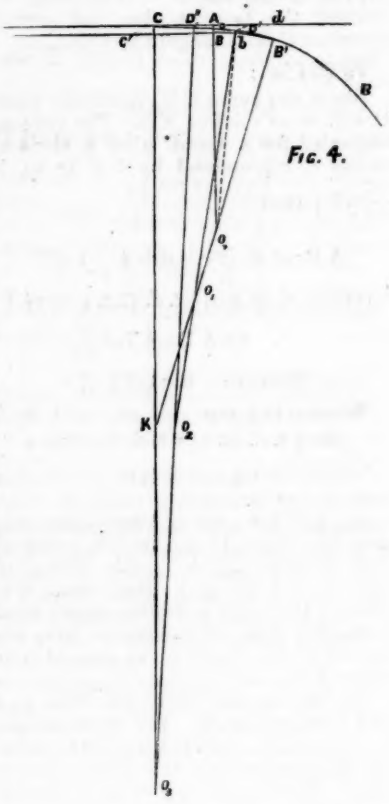


Fig. 4.

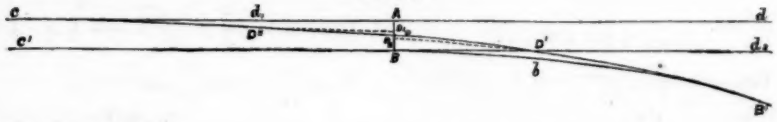
$$B D_2 = t.d.\ (r. \frac{3}{2} a) - t.d.\ \left(\frac{4}{3} r. \frac{3}{2} a\right) = \frac{9}{4} T - \frac{27}{16} = T\ \frac{9}{16} T.$$

$$D_2 D = t.d.\ \left(\frac{4}{3} r \frac{1}{2} a\right) - t.d.\ (2 r. \frac{1}{2} a) = \frac{3}{16} T - \frac{1}{8} T = \frac{1}{16} T.$$

$\therefore \quad B D = \frac{5}{8} T = D A.$

$s = A B = \frac{5}{4} T = \frac{5}{8} \frac{a^2}{r} \quad \therefore \quad a = \sqrt{1.6 \times r.s.}$

FIG. 4.A.



When a is given

$$s = \tfrac{4}{5}\, t.\, d.\, (r.\, a).$$

Points in the curve C D'' D D' B' are found as follows:

$$A\,C = \tfrac{2}{5}\, a \text{ nearly.}$$

$$A d_1 = \tfrac{1}{2}\, a \text{ nearly, } d_1\, D'' = t.\, d.(4\, r.\, a) = \tfrac{1}{4}\, T = \tfrac{1}{5}\, s.$$

$$A\,D = D\,B = \tfrac{1}{2}\, s.$$

$$B\,D' = \sqrt{\tfrac{1}{4}\, a^2 - \tfrac{1}{25}\, s^2} = \tfrac{1}{2}\, a \text{ nearly.}$$

$$D''b = t.\, d.\, (r.\, a) - t.\, d.\, (\tfrac{1}{2}\, r.\, a) = \tfrac{1}{4}\, T = t.\, d.\, (r.\, \tfrac{1}{2}\, a).$$

$\therefore$ D' is on the auxiliary tangent C' B d_2.

$$B' d_2 = \sqrt{\tfrac{3}{2}\, a^2 - t.d.\, (r.\, \tfrac{3}{2}\, a)^2} = \sqrt{(\tfrac{3}{2} a)^2 - (\tfrac{3}{5} s)^2}$$

$$d''\, B' = t.\, d.\, (r.\, \tfrac{3}{4}\, a) = \tfrac{3}{4}\, T = \tfrac{3}{5}\, s.$$

The point B' may also be found by a sub-deflection angle, whose value is

$$\frac{3}{400}\, a\, D = \angle\, d_2\, B\, B'.$$

Problem IV.—To find the length, 4 a, of a curve of adjustment, composed of four circular arcs of equal length, of radii 5 r, $\frac{5}{3}\, r$, $\frac{5}{4}\, r$, which shall connect a tangent line A C and a circular curve B b B' B of radius r, on which a cant c is due. A B = shift = s. The values of cant are $\frac{1}{3}\, c$, $\frac{2}{3}\, c$, $\frac{3}{3}\, c$, $\frac{4}{3}\, c$, c. (Fig. 4). Consider a as known; let B $b = a$ and B B' = 2 a, and proceed as in *Prob. III.* In this case, however, B' $o_1 = \frac{5}{4}\, r$, D $o_2 = \frac{5}{3}\, r$, D'' $o_3 = \frac{5}{2}\, r$, and D'' $o_4 = 5\, r$.

To find a:

Produce the arc C D'' until C $D_1 = 2\, a$, and the arc B' $D_2 = 2\, a$, and bisect C D'' D D' B' in D; D_1, D, D_2 may be considered as points in the straight line A B.

Let $T = t.\, d.\, (r.\, a)$.

$$A\,D_1 = t.\, d.\, (5\, r.\, 2\, a) = \tfrac{1}{2}\, T.$$

$$D_1\, D = t.\, d.\, (5\, r.\, a) - t.\, d.\, (\tfrac{1}{2}\, r.\, a) = \tfrac{1}{2}\, T.$$

$\therefore$ A D = T.

$$B\,D_2 = t.\, d.\, (r.\, 2\, a) - t.\, d.\, (\tfrac{2}{3}\, r.\, 2\, a) = \tfrac{1}{3}\, T.$$

$$D_2\, D = t.\, d.\, (\tfrac{2}{3}\, r.\, a) - t.\, d.\, (\tfrac{1}{2}\, r.\, a) = \tfrac{1}{6}\, T.$$

$\therefore$ B D = T = A D.

$$s = A\,B = 2\,T = 2\,\frac{a^2}{2\,r} \quad \therefore \quad a = \sqrt{s.\, r.}$$

When a is given

$$s = 2\,T = \text{chord deflection } (r.\, a).$$

The points C, D'', D, D', B' are located as follows:

D is the middle point of A B.

Point.	From A B.	From C A.
C	2 a nearly.	0
D''	a nearly.	$\frac{1}{5}\, T = \frac{1}{10}\, s.$
		From C' B d_2.
D'	$\sqrt{a^2 - \frac{1}{4}\, s^2}$	$\frac{1}{5}\, T = \frac{2}{5}\, s.$
B'	$2\sqrt{a^2 - s^2}$	$4\, T = 2\, s.$

The value of the sub-deflection angle b_2 B B' is

$$\frac{a}{100}\, D$$

The curves of *Probs. I.—IV.* are sufficient to flatten the extremities of any circular curve whose degree does not exceed 8. Any number of arcs of equal length may, however, be used. Let $2\, n$ = number of arcs; and $a = \dfrac{\text{length of curve}}{2\, n}$; then

$$s = \frac{n^2 + n}{3}\, t.\, d.\, (r.\, a).$$

The distance from C A, of any point in the curve, is

$$y = \frac{t.\, d.\, (r.\, a)}{6\,(2\,n+1)}\, (2\, m^3 + 3\, m^2 + m)$$

in which m is the number of arcs from C to the point. For B', $m = 2\, n$, and

$$y = \frac{4\, n^2 + n}{3}\, t.\, d.\, (r.\, a) = s + n^2\, T.$$

The distance, along A C, of any point from C, is

$$x = \sqrt{m^2 a^2 - y^2} = m\, a \text{ nearly.}$$

Unless the curve of adjustment be of great length, the points C, D and B' will be sufficient to fix the curve; in all cases, D is the middle point of the shift; C is on the tangent line at a distance from A = $n\, a$ nearly; and B' is on the curve

B B′B, and may be found by a sub-chord $n\,a$ and the sub-deflection angle d, B B′ $= \frac{n\ a}{200}$ D.

The numerical work will be considerably shortened if the length of the curve of adjustment be assumed and s calculated. If the gradient of the outer rail be taken as about 1 : 300, the length of curve of adjustment=25 × D, when V= 40. The calculation will be further simplified if the length of curve ÷ 2 n be a whole number.

The shift. $s = \frac{n^2+n}{3}$ T=N T.

$$T = t.\,d.\,(r.\,a) = \frac{a^2}{200} \sin 1^\circ \times D$$
$$= 0.00008722\ a^2 \times D.$$

T=T′. D. ∴ s=N. T′. D.

Tables I. and II. give values of T′ and N for different values of a and 2 n :

TABLE I.

a	T′	a	T′	a	T′	a	T′
15	.0196	37	.1194	59	.3036	81	.5723
16	.0223	38	.1259	60	.3140	82	.5865
17	.0252	39	.1327	61	.3246	83	.6009
18	.0283	40	.1396	62	.3353	84	.6154
19	.0315	41	.1466	63	.3462	85	.6301
20	.0349	42	.1539	64	.3573	86	.6451
21	.0385	43	.1613	65	.3685	87	.6602
22	.0422	44	.1689	66	.3799	88	.6754
23	.0461	45	.1766	67	.3915	89	.6908
24	.0502	46	.1845	68	.4033	90	.7065
25	.0545	47	.1927	69	.4153	91	.7223
26	.0590	48	.2010	70	.4274	92	.7382
27	.0637	49	.2094	71	4397	93	.7544
28	.0684	50	.2180	72	.4522	94	.7707
29	.0734	51	.2268	73	.4648	95	.7872
30	.0785	52	.2358	74	.4776	96	.8038
31	.0838	53	.2450	75	.4906	97	.8206
32	.0893	54	.2543	76	.5038	98	.8376
33	.09498	55	.2638	77	.5171	99	.8548
34	.1008	56	.2735	78	.5306	100	.8722
35	.1068	57	.2834	79	.5443		
36	.1130	58	.2934	80	.5582		

TABLE II.

2 n	N	2 n	N	2 n	N	2 n	N	2 n	$N = \frac{n^2+n}{3}$
1	$\frac{1}{2}$	3	4	5	$\frac{35}{12}$	7	$5\frac{1}{4}$	9	$8\frac{1}{4}$
2	$\frac{2}{3}$	4	2	6	4	8	$6\frac{2}{3}$	10	10

Example.—Given B B′B, a $6\frac{1}{2}$° curve, and 2 n=4=number of arcs in curve of adjustment ; to find the shift, s, when the gradient of the outer rail is about 1 : 300 and V=40.

Length of curve=25 × D=162′, make a=40.

Table I.—a=40 T′=0.1395.

Table II.—2 n=4 N=2.

∴ s=2 × 0.1395 × 6.5=1.′81=1′ 9.″7.

The curve B B ′B. When the tangent points A, A′, (Fig. 1.) are fixed and the degree of the curve A A A′ is known, the shift may be calculated for this curve, since A A A′ and B B′ B B″ may be considered of the same degree. In staking

out the curve A A A′, a point, at each end of the curve, corresponding to B′ may be found, very approximately, by using the sub-chord $n\,a$ and the sub-deflection angle whose value is $\frac{n\,a}{200}$ D; B B′B is then located by shifting every stake of A A A′ through a distance = A B = shift.

When the angle of intersection of the two tangent lines is given and the degree of the connecting curve is known, it will often be convenient to take this degree as the degree of BB′B and to locate the curve between the auxiliary tangents B_1 B, B″B_1. In this case the distance from I the point of intersection of the tangent lines to A or A′ is

$$A\,I = A'I = (r+s)\tan\tfrac{1}{2}\angle I.$$

In practice, curves of more than 6° are seldom met with; therefore in the great majority of cases, one or two arcs in the curve of adjustment will be sufficient to flatten the extremities of the curve; it will be convenient in these cases, to make the length of an arc of adjustment = 100′ in which case the tangent deflection will be found directly from the tables of Henck's Field Book and the shift will become

$\frac{1}{4}$ T or $\frac{2}{3}$ T, according as one or two arcs are used.

In the absence of tables

Shift (for one arc) = $\frac{1}{4} \times .8722 \times$ D = 0.218 D.

Shift (for two arcs) = $\frac{2}{3}$ .8722 × D = 0.581 D.

The value of the deflection angle d, B B′ (Fig. 4 A,) will then be $\frac{1}{4}$ D for curves or one arc, $\frac{1}{2}$ D for curves of two arcs.

COMPOUND CURVES.

When, in passing from one branch of a compound curve to the other, the change of cant is small, that is to say, when D ~ D′ $\leq$ 2, the shifts of the two branches may be made equal, and the change of cant between the branches "humored in." The shift should be calculated for the sharp branch and from this the length of the curve of adjustment for the flat branch.

When D ~ D′ > 2, one arc of adjustment of degree $\frac{D+D'}{2}$ giving two equal changes of cant, will, in the majority of cases, be sufficient to correct the branches of the curve.

Let A′ A of radius R and degree D and A A″ of radius R′ and degree D′ be the two branches of the compound curve A′A A″, Fig. 5; and let the length of the arc of adjustment be $'a'$ and its radius r; then $r = \frac{2\,R\,R'}{R+R'}$ for r : R = D :

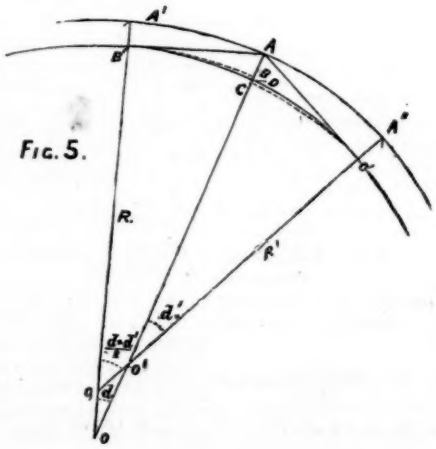


FIG. 5.

$\frac{D+D'}{2}$ (Fig. 5.) and $R+R' : R'=D+D'$: D from which $r=\frac{2RR'}{R+R'}$

Let B B′ and C C′ be the shifted positions of the branches of the compound curves, since the shifts are comparatively small, we may say, radius of B B′=R and radius of C C′=R′. Consider $'a'$ as known and let the shift A A″=A C=*t. d.* (R′. $\frac{1}{2}a$) and the shift of A′A=A B=*t. d.* (R+$\frac{1}{2}a$), then will B′A∼C′A. Draw the radii B′O, A O, C′O′ and let d and d' be the central angle; produce C′ O′ until it cuts B′ O in O_1 then B′ O_1 C′=$\frac{d+d'}{2}$ and since A B′ = A C′, O_1 will be the centre of a circle passing through B′ and C′ and tangent at these points to B′ B and C′ C. The middle point D of this arc is on the line A C, *i. e.* B′ D=B C′=$\frac{1}{2}a$.

To find $'a'$ and the position of D:

$$AD=t.d.\left(\frac{2RR'}{R+R'}\cdot\frac{1}{2}a\right)$$

$$BD=t.d.\left(\frac{2RR'}{R+R'}\cdot\frac{1}{2}a\right)-t.d.(R\tfrac{1}{2}a)=\frac{a^3}{8}\cdot\frac{R'-R}{2RR'}$$

$$DC=t.d.\ (R'\tfrac{1}{2}a)-t.d.\left(\frac{2RR'}{R+R'},\tfrac{1}{2}a\right)=\frac{a^3}{8}\cdot\frac{R'-R}{2RR}=BD.$$

$$\therefore\quad BC=2BD=\frac{a^3}{8}\cdot\frac{R'-R}{RR'}.$$

And D is the middle point of B C.

Find the length of the curve of adjustment which shall connect the sharp branch of the curve and its tangent line, and from this find the value of the shift A C; A C=*t. d.* (R′. $\frac{1}{2}a$)= T′, D′, from which, by Table I., may be found the value of C C′=$\frac{1}{2}a$; find also A B=*t. d.* (R. $\frac{1}{2}a$)=T′, D, which is the value of the shift of the flat branch, and from which the length of the curve of adjustment which shall connect it with its tangent line must be calculated.

Example.—A A″, the sharp branch is a 5° 30′ curve, and has a curve of adjustment of 3 arcs, of 40′ each; A′A is a 3° curve, which is to have a curve of adjustment of 2 arcs.

Shift=A C=N T'_{40}.D′=$\frac{1}{4}\times.1396\times5\frac{1}{2}$ =.1745×5½=.959′.

=*t. d.* (R′. $\frac{1}{2}a$)=T'_1 D′ ∴ $T'_1=\frac{.959}{5\frac{1}{2}}$ =1745.

Entering Table I. with this value we have $\frac{1}{2}a$=45′ nearly.

∴ B′ D C′=90′ approx.

Shift for flat arc=A B=T'_1 D=.1745×3 =.5235′=N T D=$\frac{2}{3}$. T′ .3 = 2 T′, ... T′=.2617.

Entering Table I., we find that the length of an arc of adjustment to be 55′ nearly.

A D=½ (A B+A C) = .741′.

REVERSED CURVES.

Let B A C be a reversed curve, and A the point of reversing; determine the length 2 *n a* of the curve of adjustment, and let A B′ (Fig. 6) = *n a*. Find the value of

$$\frac{AB'.AO'}{AO}=\frac{n\,a.\,r'}{r}$$

and let this be the value of $n'a'$=A C′, ∠:*e.* ½ length of the curve of adjustment for the flat branch of the curve; draw the radii *o* B′, *o′* C′ which will be parallel, and consequently a line drawn through A perpendicular to *o′* C′ will be perpendicular to *o*B′; moreover *d*B′=*t.d.* (*r. n a*) = n^2T, and C′ d_1=*t. d.* (*r′. n′ a′*) = n'^2 T_1. With *o* as centre and *o*′*d* as radius describe the arc B_1 *d*, and with *o′* as centre and *o′* d_1 as radius describe the arc d_1 c_1 and join *d* d_1, which will be tangents to both arcs.

Calculate the shift for the arc B_1 *d*, the length of the curve of adjustment being 2 *n a*; also calculate the shift for the arc d_1 c_1, the length of the curve of adjustment being 2 *n′ a′*. Since the distance B′*d* is small compared with *r* we may say

Shift for B_1 *d*=*d b′*=$\frac{n^2+n}{3}$ *t. d.* (*r.a.*)

So also

Shift for c_1 d_1=d_1 *c′*=$\frac{n'^2+n'}{3}$ *t.d.*(*r′.a′*)

The curve of adjustment for B_1 *d* bi-

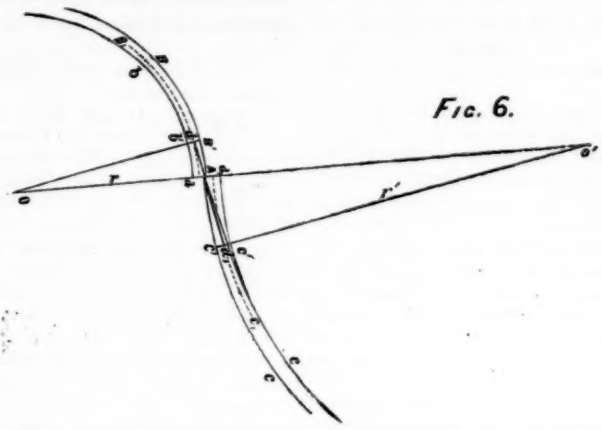


FIG. 6.

sects $d\ b'$ and the curve of adjustment for $c_1\ d_1$ bisects $d_1\ c'$.

These curves are tangent to d A d_1 at A.

The total shift,

For B A $=$B$'$ $b'$$=$A $a$$=n^2$ T$+\frac{n^2+n}{3}$ T$=$

$$\frac{4n^2+n}{3}\text{ T.}$$

For c A$=$C$'$ $c'$$=$A $a_1$$=n'^2$ T$_1+\frac{n'^2+n}{3}$ T$_1$

$$=\frac{4n'^2+n'}{3}\text{T}_1.$$

These are, of course, the values of the shifts at the ends of the curve from which the lengths of the curves of adjustment which connect the curve and its tangent lines must be calculated.

Example.—B A the sharp branch of a reversed curve is of 6°, at its junction with the other branch it is to have a curve of adjustment of 6 arcs each of 20′, and a curve of 4 arcs is to connect it and its tangent line. The flat branch A C is of 4° 30′, at its junction with the first branch it is to have a curve of adjustment of 4 arcs and a curve of 2 arcs is to connect it and its tangent line.

$n\ a=3\times20=60, n'a'=\frac{6}{4.5}\cdot60=80\ \therefore\ a'$

$$\frac{80}{2}=40'.$$

Shift for B A$=\frac{4\ n^2+n}{3}$ T$=\frac{4\ n^2+n}{3}$T′D$=$

13 T′ D′$=$78 T$=$78$\times$.0349$=$2′.728.

Shift for C A$=\frac{4n'+^2n'}{3}$T$=6\times4\frac{1}{2}\times$T′$=27$

$\times$.1396$=$3.′77.

At the ends of the curve we have

For B A$_1$ shift$=$2.72$=$N T′D, N T′$=$ .4537 here N$=\frac{n^2+n}{3}=$ 2 $\therefore$ T′$=$.2268 and $a=51=$length of an arc of the curve of adjustment which connects B A and its tangent line:

For CA$_1$ shift$=$3.77$=$N T′ D. Here N$=\frac{2}{3}$ 1. T′$=$1.2564 and $a=120'$ approximately.

TIDAL SCOUR IN RIVERS.*

By Mr. C. RICHARDSON.
From "The Engineer."

The object of this paper is to draw the attention of this section to a few facts bearing upon the question, "Do the tidal waters in ebbing and flowing along a river channel tend to keep that channel open?" The channel of the Avon between Kingroad and Bristol will naturally occur to every one present here, and on that channel our remarks shall begin; but it will be necessary to bear in mind, throughout this discussion, that the form of the channel through the alluvium alone is considered. Wherever

* A paper read before the British Association.

rock or other hard substance appear, the conditions of the question are entirely changed, and the facts mentioned may no longer apply.

Now, if the river channel be carefully inspected at low water of a spring tide, flakes of mud may be observed to slip down into the low-water stream here and there as the tide recedes ; the hollows these mud-slips leave are characteristic, and are plainly observable all along the river at low water. These patches of mud slip into the low water channel as they lose the support of the tidal water, and are then carried out into the Severn by the stream. The low water section across the Avon, as above described, will be found to apply to the whole length of the channel from Pill to Bristol, with the exception that towards Pill the low water channel is something wider than it is higher up the river, but the mud slopes will be found at about the same angle.

This fact clearly indicates two things: first, that the mud has been deposited by the tidal waters—for how else did the mud get there? and, secondly, that the means of carrying it off resides in the low water current, for otherwise the accumulation of these mud-slips would gradually raise the level of the low water channel, a fact which is against all experience.

In what has been said above, the action of wind has been left out of the question, and these observations are supposed to have been made at those times when there was little or no wind to affect them. It will be found, however, that the action of the wind, where it can be well observed, tends to prove the same fact, namely, that the tidal waters do deposit the mud in quiet times. For example, at the ferry from Pill to Lamplighter's, the Lamplighter's shore is entirely alluvial, and it will be found that during a quiet season the mud on that shore will rise to a level of 5 ft. or 6 ft., on both sides, above the level of the ferry path. If, after this, a continuance of strong westerly winds sets in, the ripple on the water will gradually wash away the accumulated mud again until it becomes almost level with the ferry path. This fact proves that the tidal waters do, of themselves, have a tendency to deposit mud, but that the ripple caused by the wind washes it away again in exposed situations near the mouth of the river.

Looking now at other streams under similar circumstances, one of the largest on the same shore is the Main Reen, which runs into the Severn at Chessel Pill, at the new passage. The history of this stream is instructive. First of all, it was dammed at the old footbridge at Redwick, a mile inshore, representing very fairly the damming of the Avon at at Netham, if due allowance is made for the comparative volume of the two streams. The commissioners then, for the benefit of the level, built a new dam near the mouth of the stream. This would be like damming the Avon at Hungroad. And what has been the result? Inside the dam the mud slopes have become grass-grown ; but outside the dam there is no perceptible difference in the external channel. It has no tendency to mud up or alter in any way ; the channel is just as wide and as deep, and the mud slopes remain the same, mud-slips taking place into the stream at low water, and being washed away by the fresh water in the same way as has been described.

Looking next at the smaller streams, what do we see? That the tidal channels or estuaries are solely and entirely governed in their dimensions by the quantity of fresh water that comes down. The writer intended to have gauged the flow of water and to have measured the tidal channels of a number of these, but he had not time to do so. He has not the least doubt that if this had been done it would have been found that the tidal channel, in its dimensions, always bears a direct proportion to the quantity of fresh water that comes down.

This fact is quite apparent to any one who has been in the habit of observing these things ; he will look carefully at the different streams in the neighborhood, he will see little streams with little estuaries, medium streams with middle-sized estuaries, and big streams with large estuaries, the channel formed being always in proportion to the amount of fresh water. This cannot be accounted for on any other supposition than that the volume of the fresh water determines the size of the estuary, and that the tidal waters have nothing at all to do with it.

THE EFFECT OF DEAD SPACE IN WOOLF ENGINES.

By O. HOLLAUER.

Translated from Bulletin de la Soc. Indust. de Mulhouse.

I.

This important question of dead space in the case of single cylinder engines has been treated by Zeuner in *La Theorie Mécanique de la Chaleur*, page 493 of Arnthat and Cazins translation.

In this remarkable work the author first considers the case of a one cylinder engine without dead spaces consuming a weight M of mixed steam and water, leaving the boiler to fill the initial volume $V_1 = 0.^m04949$ offered by the cylinder during admission; the total volume being $V = 0.^m29698$. He then calculates work due to full pressure $V_1 p_2$ and expansion; using the exponent $M = 1{,}035 + 0{,}100\, x_2$ in the formula

$$L_4 = \frac{p_2 V_1}{m-1}\left(1 - \left(\frac{V_1}{V}\right)^{m-1}\right)$$

Then he estimates all losses due to imperfection of cycle, incomplete expansion, loss of pressure between boiler and cylinder, inequality between external pressure and counter pressure; loss due to constant resistance and the variable resistance of friction; and he deduces 7.72 k as the hourly consumption per H. P., corresponding to an admission of one-sixth.

Then, considering an engine with dead spaces, he says:

"Dead space exerts an important influence upon the working. Its inconveniences are mainly due to the fact that steam is admitted into a space holding steam of feeble tension, so that the engine uses more than one without such dead spaces. It is true that the work which corresponds to this additional mass of steam is not entirely lost since it shares in the expansion. In spite of this that work is too great to be neglected."

The weight of the steam admitted into the dead space and the volume generated $(V' + V_1)$ is $M_1 > M$, that was consumed in the preceding case, and the author proves that there is evaporation of water during the introduction of the steam into the cylinder, in consequence of the dead spaces.

He afterwards considers: (1) the loss due to imperfection of cycle; (2) that due to dead space; (3) to difference of tension in boiler and cylinder; (4) to inequality of counter pressure and exterior pressure; (5) to the constant resistance of friction; (6) to the variable resistance of friction. He finally fixes as the rate of hourly consumption per effective horse power, $8.478\, k'$.

The suppression of the dead space $V' = 0{,}01485$ cubic metres, when the volume generated was $V_1 = 0{,}04949$ C. M. reduces the consumption

$$\frac{8{,}478\ \text{k} - 7{,}720\ \text{k},}{8.478} = 8\ \%,\ 94.$$

To prevent this, Zeuner attempts to condense the escaped steam until the tension in dead spaces is equal to that in the boiler. Remarking that this causes a new loss of work which may balance the gain of the process, he says:

"When, in an ordinary engine, the condensation of steam behind the piston is kept up until that which is in the dead spaces reaches the same point as that in the boiler, the engine then acts as one without dead spaces, so that the escape of steam goes on during the entire stroke of the piston."

He finally proposes that the steam may be superheated when the limit of condensation is reached. "While the piston retrogrades a certain space a corresponding volume of steam leaves the cylinder; the steam remaining behind probably contains little water. Now, as the mixture is compressed there will probably result a partial or total vaporization of the water; and it may happen that at the limit of the compression the steam in the dead space will be superheated. Unfortunately, we do not yet know how the mixture of this superheated vapor and the saturated steam from the boiler is effected; but this question is here of little importance; our main object being to show that compression is accompanied by a vaporization of the

water mixed with steam, so as to cause superheating the steam left behind."

It is to be regretted that Zeuner has not taken into account the disturbing effect of the walls of cylinders; an effect pointed out by Hirn in his edition of 1865; which experiments have established beyond a doubt, even in the case of superheated steam.

The walls which absorb heat during admission, condense often a considerable portion of the steam which flows from the boilers, and restore a part during the period of expansion. This occurs by means of the coating of water which covers them. This evaporates and increases the amount of steam on the cylinders. The action is quite complicated, and modifies in a great degree all the series of phenomena of which work is the resultant. It seemed impossible to neglect its effects in the deterioration by experiment of the influence of compression and loss by dead space upon consumption.

In previous publications in the *Bulletin*, we have given the loss due to dead space; but the method followed in the evaluation was not attended by all the checks required in experimental researches; the purely algebraical discussion depending upon a hypothesis not physically warranted.

After having determined upon the same curves the exponent of the law of expansion, formulas for work are determined, evaluated for dead spaces both for single cylinder and Woolf engines. The values so obtained are very close to those determined by the planimeter upon the diagram areas.

For the same engines, supposed without dead spaces, exactly the same volume of steam is admitted as in the former case; and the work is estimated on the hypothesis that the exponent of expansion remains the same. The difference between the values obtained should give the amount of loss. But all this depends on the unproven hypothesis that the exponent of the law of expansion is the same when the same volume is introduced into a cylinder either with or without dead space. The examination of many diagrams from the same motors, with different admissions, has proven that the exponent varies with the volume introduced. Are we to conclude that it will not vary for engines with and without dead space, or that the exponent remains constant for the same volume admitted whatever the amount of dead space?

Take first the case of single cylinder engines, in which the dead space may be reduced to a small fraction of the volume generated, and let us seek for the manifold causes which influence the approximate law of expansion denoted by the exponent m or a. As in this kind of engines the discharge steam is not greatly compressed, all the walls of the dead space, as well as the cylinder, are cooled during the period of discharge into the condenser.

When the next charge of steam comes from the boiler, it encounters walls not sufficiently heated by the compression and condenses, giving up a considerable quantity of heat. This condensation may amount to 60 per cent. of the steam admitted when there is no jacket.

The heat is partially restored during expansion; it allows a continual evaporation of the coat of water which covers the walls previously warmed. At last the envelop of steam diminishes condensation and increases evaporation in the cylinders. These processes, combined with the disappearance of heat due to expansion, are the two sole causes that affect the law of expansion, and fix the value of the exponent of that law.

Suppose the dead spaces removed, and that the same volume of steam is introduced into the cylinders. As the surfaces differ, the condensation during admission and the evaporation during expansion will be changed, as well as the work of expansion; all being causes that modify the exponent of the law of expansion, and which show the falsity of the hypothesis upon which the formulas for work have been based. But as the dead space in single cylinder machines, especially such as those of Hirn & Corliss, is quite small relatively to the final volume, these formulas can be applied with sufficient approximation.

But this is not the case with the vertical Woolf engines, in which the dead space between the two cylinders is enormous; as, for example, in that of Dollfus-Mieg; in which it is, for the small cylinder one-thirtieth, for the large one-eighth of the total volume. In a pre-

vious paper we have indicated the distinction that must be made between the two simultaneous losses due to dead space and condensation between the cylinders. But this correction does not remove the error inherent in those formulas which are based upon the hypothesis that the exponent is the same.

We must analyze the transformations of the steam during its passage through the dead spaces and during compression; an analysis which alone can give satisfactory results by giving us the key to the thermic phenomena that take place in the dead spaces.

We will give in full detail the results obtained by us in the solution of this problem.

The Woolf engine of 200 H. P., which was the subject of our investigations, has two cut-offs. The steam of the small cylinder escapes into the distributing chest of the larger. The compressed steam is contained under the small piston and between these two cut-offs, which have just the same motion.

The pressures were determined by Watt's indicator with sufficient exactness. The usual objections to this instrument, which are founded upon circumstances due to the use of a spring in regulating the movement, do not hold in the case of a Woolf engine admitting at full pressure during almost its whole stroke. The springs do not have to bear sudden changes of pressure as in the case of single cylinders with great expansion; so that the inertia and friction of the different pieces may be neglected.

Again we traced upon the sheet containing the curves, according to Zeuner's method, the diagram of distribution which allows us to follow the movement of the slides and to control the positions for the critical points of work, as shown by Watt's indicator.

Consider the small piston at the beginning of its course. The steam enters from the boiler during the entire period of admission and becomes mingled with that in the dead spaces. When it has left the boiler to enter the cylinder a mixture of 0,6956 k containing 0,0278 k of water, which the weight of saturated steam

0,2362 cub. m. $\times$ 2,3780 k = 0,5617 k.

A part of this steam condenses upon the walls.

0,6956 + 0,0125 k remains in the dead space, less 0,5617 k, or $20\frac{67}{100}$ per cent. Subtracting 4 per cent. of water, there remains $16\frac{67}{100}$ per cent. of condensation.

The small slide during lap intercepts communication. Expansion lasts until the moment when the escape opens. The steam immediately enters the dead spaces between the small and large cylinder; then, the advance to admission being slower than that to escape, it passes immediately into the large cylinder, when the port has opened. This discharge with expansion is interrupted at about fifteen-twentieths of the course by the exterior lap of the large slide closing the admission orifice; and there is between the small piston and the port of the large cylinder a volume of compressed steam, viz.:

0,0806 cub. met. under the small piston and in the port of the small cylinder.

0,0890 cub. met. between the small slide and the port of the large.

Making a total of 0,1696 cub. met. at a pressure of 0,650 kil., giving a weight of saturated steam of 0,1696 cub. met. $\times$ 0,3913 k. = 0,0664 k. But we must know the quantity of water, whether in suspension or deposed upon the walls, in order to be able to determine the total internal heat U of the mixture. The curve from the large cylinder gives the weight of water as exactly as possible.

As soon as the large slide closes there is in the large cylinder 1,4176 c. m. of saturated steam at 0,620 k. pressure, weighing 0,4176 c. m. $\times$ 0,3744 k. = 0,5307 k. With this we are to compare 0,6956 directly gauged and furnished by the boiler at each piston stroke, increased by 0,0223 k., which remain in the large cylinder after the escape to the condenser. For the liquid in the steam

0,6956k. + 0,0223 k. $-$ 0,5307 k. = 0,1872k.

or

$$\frac{0{,}1872}{0{,}66956 + 0{,}0223} = 26\,\% +$$

We may without appreciable error suppose that this proposition was the same in the small cylinder at the instant of interruption, the two cylinders having been in full communication up to

this moment. The mixed steam and water between the small piston and the port of the large slide at a tension of 0,065 k. is composed of 0,0664 k. of steam, and $0{,}064 \times \frac{0{,}1872}{0{,}5307} = 0{,}234$ k. of water.

Total, 0,0898 k.; of which the internal heat

$$U = 0{,}0664\ q + 0{,}0898\ q$$
$$= 0{,}0664\text{ k} \times 505{,}76\text{c} + 0{,}0898\text{k} \times 87{,}88\text{c}.$$
$$= 33{,}58\text{ c.} + 7{,}89\text{ c.} = 41{,}47\text{ c.}$$

Is this heat augmented by the compression?

This can be easily determined by finding the composition of the mixture 0,0898 k.

At sixteen-twenty, seventeen-twenty, eighteen-twenty of the course, points at which we find the pressures

0,723 ; 0,850 ; 0,993 k.

and consequently :

Pressures.	t	q	q	β	Volumes	Steam.	Water.	%	U
0k,723	90°,31	90c,69	503c,57	0k,43252	0^{m3},4598	0k,0691	0k,0207	23%,05	42c,94
0k,840	94°,63	95c,06	500c,45	0k,50353	0^{m3},4448	0k,0729	0k,0469	48%,82	45c,09
0k,993	98°,89	99c,37	496c,78	0k,58271	0^{m3},1299	0k,0757	0k,0441	45%,70	46c,53

REPORT OF IRON AND STEEL INDUSTRIES—METALLURGICAL TECHNOLOGY.*

Journal of the Iron and Steel Institute.

MAGNETISM OF IRON.—It has generally been accepted that iron at a red heat was incapable of being rendered magnetic, and this was sustained by Elias, in *Poggendorf Annals* for 1872; the reverse of this is now, however, maintained by M. Gaugain, in a communication to the Academy of Sciences, in Paris, February 1st, who states that if it is wished to saturate a bar of iron with magnetism, the best method of doing so is to magnetize it whilst its temperature is very elevated.

MAGNETISM OF STEEL.—Commandant Treve has communicated to the Academie des Sciences the results of experiments made by himself and M. Durassier, the head of the chemical department at the Creusot Works, on the connection which exists between the nature of steel and its magnetic force. Fifteen bars of steel were selected, which were divided into five sets, each of which received a different temper, after which M. Treve magnetized them to saturation, and then determined their magnetic force by the method of deviation. Those bars which contained 0.950 per cent. of carbon, and which were hardened in cold water, gave a maximum of deviation represented by the number 47; whilst a bar with the same amount of carbon, but hardened in boiling water, gave the number 44: and a third bar, also with the same amount of carbon, but hardened in oil of a temperature of 10° Centigrade (50° Fahrenheit) only gave 43, showing that the fluid used in hardening exerts an influence. The effect of the amount of carbon contained in the steel is also established, for whilst the maximum of deviation of the above-mentioned bars, which contained 0.950 per cent. of carbon, was found to be 47, other bars containing 0.250 per cent. of carbon only showed a deviation of 13. In laying down the curves of variation, the influence of the amount of the carbon and of the hard-

* Taken from the report to the Iron and Steel Institute by David Forbes, F. R. S.

ening media was sensible enough, but the effect of the latter was smaller in proportion as the former increased, and M. Treve has ascertained the fact that the magnetic curve of a steel bar coincides with its curve of elasticity, thus proving that carbon not only gives to steel its elasticity but also its magnetic capacity.

Magnetic Separation of Iron and Steel.—Some time ago we called attention to certain machines which were employed on the river St. Lawrence, in Canada, for concentrating by means of magnetism the ferruginous sands so abundant in those parts, and in which the iron existed in the state of the native magnetic oxyde of this metal; we now call attention to a somewhat similar arrangement called a magneto-mechanical separator, which has for object the separation of iron and steel filings from the copper, brass, and other filings, which accumulate in the workshops. The machine is the invention of Mr. Charles Vavin, and was described by M. Bouillet at the meeting on the 1st May of the Société d'Encouragement des Arts, &c. We must refer to the original source for details, but it may be mentioned that the mixed filings fall on two cylinders placed one above the other, and furnished with rings of soft iron, which are rendered magnetic by strong artificial horse shoe magnets of iron, placed as radii. Effective arrangements are made in order to render active the entire surface of the cylinders, and a brush of pig's bristles detaches the adherent filings. It is stated that the separation proceeds very well, and that a machine not costing more than £60 is capable of cleaning half a ton of filings per day. Judging from the description, however, we should be inclined to give preference to the machine used at Quebec, which has already been noticed in a former report.

Reducing Iron Ores with Lignite.—The importance of the question as to the possibility of smelting iron ores economically, by means of the, geologically speaking, younger carboniferous deposits of such as the brown coals and lignites (which, in many parts of the world otherwise altogether deficient in true coal, as we are accustomed to call the mineral of carboniferous age, are found as immense deposits), is probably not fully appreciated in this country where we are so abundantly supplied with the real article, yet it is a question which is attracting more and more attention on the Continent. Under the head of Greece, we have briefly alluded to some trials made in order to smelt the Seriphos brown hematites with the tertiary lignites of Koumi, which experiments cost a large sum of money and turned out a complete failure, but attempts to use a mixture of lignites with the coke in the blast furnace appear, recently, to have been, at least in some instances, more successful; thus we find in the *Kaerntln. Zeitschr.*, for 1875, p. 135, an account given by E. Heygrowsky of trials made at the Zeltweg blast furnaces, which proved that it was possible to replace up to 40 per cent. of the cokes by raw brown coal from Fohnsdorf, with the result that the Bessemer pig produced in the furnace was not only about 10s. per ton cheaper, but also was somewhat purer than when made with the cokes alone, the author considering that when using lignite it is very important to have a wider furnace with a strong and highly heated blast; much more tar is, however, deposited in the gas tubes, which require to be so arranged that they can easily be cleaned out.

We also learn from the *Oesterr. Zeitschr. fur Berg.*, 1875, s. 120, that some experiments have lately been made at the Proevali Iron Works, in order to smelt the Huettenberger brown hematite, in a Siemens rotary furnace, with lignite, but the result was altogether unsatisfactory in an economic point of view, the product being in part useless, full of slag, and not by any means uniform. Trials made by adding to the charge of the coke blast furnace as much as 33 per cent. of the lignite from Lieschaer, appeared, however, to work tolerably well.

In the *Berg und Huettenmaennische Zeitung* for last year, No. 24, will be found a communication treating more at length upon the same subject by R. Von Reichenbach, in which, after giving a summary of the experiments and proposals already made by Gersdorff, Wagner, Mietsch, Khern, Siemens, and others, he suggests that further trials should be

made on the following plans: (1) with the older lignites, by employing a comparatively low blast furnace with an extremely hot blast to prevent the coal sintering; (2) with the more recent lignites, by first drying them so as to expel all moisture and chemically combined water, and use them as above; (3) by further attempts at coking the lignites; (4) in cases where there are large quantities of very small coal, to use this for the reduction of the ore in one furnace or part of a furnace, and afterwards smelt it by the coarse coal; (5) and lastly, to smelt the iron ores by the gases produced from the lignites in generators.

Still more recently our attention has been directed to the *Berg und Huettenmaennische Zeitung* for the 11th June this year, in which M. A. Kerperly communicates a description of a furnace recently patented by L. Nessel, of the Friedrich's Furnaces, at Rokitzan, in Bohemia, for smelting iron with brown coal or lignite.

Manganiferous and Phosphoric Pig Iron.—An exhaustive paper, by M. H. Le Chatelier, has appeared in the *Annales des Mines*, vol. 6, p. 216-244, for 1874, entitled "Notes taken during a tour in Belgium, on the manufacture of cast irons, containing manganese and phosphorus at the same time, and on their employment in the manufacture of fine-grained wrought iron." The production of good wrought iron at the works of Ougrée, Grivegnée, Dolhain, and l'Espérance, in Belgium, from iron ores containing from 1 to 2 per cent. of phosphorus, which amount is afterwards in great measure expelled in the operation of puddling, and the part played by manganese in this operation, has been carefully studied by M. Le Chatelier, whose experiences are given at some length, and whose paper is well worth perusal by all interested in the subject.

Natural Gas as Fuel.—The success attendant upon the employment of the natural gas from boreholes in several parts of Pennsylvania, as has been alluded to in previous reports, has encouraged a large number of trials being made to extend its application. At Apollo, the whole of the heating furnaces and steam boilers of the ironworks are now kept supplied with natural gas from a well sunk to the depth of 1,250 feet in search of it, and it is said that a combination of ironmasters, consisting of Messrs. Lewis, Bailey, Dalzell & Co., Spang, Chalfant & Co., and Graff, Bennett & Co., have acquired the Butler gas well, and are about to convey the gas in pipes, the distance of some twenty miles, in order to use it at their ironworks. In March, Messrs. Spang, Chalfant & Co. were still boring for gas in their works at Pittsburgh, as also were Messrs. Reis, Brown & Berger, of Newcastle, who had already got down some 1,800 feet. In Ohio, also, the Niles Iron Company were putting down a gas well, as they are called, at their rolling mills at Niles, but the attempt made at the Leetonia Iron Works had been abandoned after getting down 1,500 feet.

Mechanical Puddling.—A communication by Dr. Durre, of Aix la Chapelle, relative to the advances made in mechanical puddling with special reference to the use of the Pernot furnace, illustrated by drawings of the furnace of Pernot, Spencer, and Howson and Thomas, has appeared recently in the *Zeitschrift de Vereines deutscher Ingenieure*. After a short review of the results obtained up to date in the furnaces of Danks, Sellers, Crampton, Howson & Thomas, Spencer & Pernot, the author expresses himself in favor of the last-named furnace, principally for the reasons that the mechanical motion is more favorable to the work itself, and the furnace bed is more easily fitted and accessible during the operations, whereby the production of smaller blooms can be more easily managed.

Ehrenwerth's Rotary Puddling Furnace.—The *Bulletin du Musée de l' Industrie* contains a description of this furnace, from which the following is abstracted: It consists of a revolving hearth fixed on a vertical shaft, and formed of a cast iron bottom and a flange plate. The entrance of air to the furnace is prevented by a cylinder of sheet iron, fixed to the hearth or flange plate, and dipping into an annular trough in which water continually circulates. The mode of cooling the sides of the furnace

differs according as this cylinder is fixed to the hearth or flange plate; in the former instance, the sides being hollow, the cold water is led under pressure in pipes to the hollows, and the flow takes place in the trough above the lower edge; whilst in the latter case the water is forced against the sides of the hearth in small jets crossing one another, and then runs into the trough. Motion is communicated to the hearth shaft by means of a pair of cog wheels driven by a belt from the main shaft.

The heating of the furnace may be by an ordinary fire grate or by gas, and when it is charged, the hearth is put in motion at the rate of 20 to 24 revolutions per minute, and as soon as the pig begins to melt it is worked about with rabbles provided with peels placed obliquely. These rabbles, which have a notch so as to rest on cones in the furnace doors, are moved from the edge of the furnace to the centre and back again, either by hand or by engine power. By placing these peels at two contrary angles, one works the iron which is being puddled towards the interior of the furnace, and the other towards the exterior, so that, by the combination of these movements, with the rotation of the hearth itself, the molten metal is kept in continual agitation.

The balls are made by the puddler as usual, the hearth being only made to revolve from time to time, when one ball is ready, so as to place a fresh quantity of metal before the working door. In order to bring the balls to as uniform a temperature as possible, the hearth is again rotated, the balls returned, and taken out and shingled as usual. The slag in the furnace is then tapped out through two inclined holes left in the flange plate, or it may be ladled out.

One furnace, having two working doors, into which from 15 to 20 tons pig iron are charged at a time, requires four puddlers to work it or three puddlers and a stoker, if the metal is worked by engine power.

Flattening Plate Iron.—In the Bay State Iron Works, at Boston, U. S., a very simple method for flattening plate iron can be seen in use; a heavy roller, worked by machinery, rolls over the plate, which is brought opposite to it; this roller is propelled by a rack and pinion, and, after moving over the plate, it is reversed and rolls back to its original position. In this instance, an old plate roll, with the coupling ends and part of the journey turned off, forms the roller weight employed.

Definition of Steel.—In the *Revue Universelle* and in the first and third of this year's numbers of the *Annuaire de l' Association des Ingénieurs sortis de l' Ecole de Liége*, we find the discussion still continued as to the true signification of the term steel, which commenced when Mr. Greiner, the head of the steel department of the Seraing works (whose name by a typographical error is spelt Gruner in our second report for 1873), defined steel to be any malleable product of the iron industry obtained in a state of fusion, an opinion to which Mr. Hackney, in his paper on the steel manufacture, read lately before the Institution of Civil Engineers, also subscribes; but as this would oblige us to class soft iron made by the Bessemer process, or pure iron cast in a crucible, as steel, although neither of these products will receive a temper, which from the oldest times has been looked upon as the all-characteristic property of steel, we do not think Mr. Greiner's definition is likely to meet with universal acceptance.

Annealed Spiegeleisen.—As it is well known that the objection to the use of spiegeleisen in the production of the extra soft steel and Bessemer iron made by the Bessemer process is the high amount of carbon which it contains, for which reason ferro-manganese is always preferred in such cases, Professor Raymond has proposed in a paper read before the American Institute of Mining Engineers in February, to employ instead of the ordinary spiegeleisen such as had previously been annealed, or more properly speaking decarbonized, by heating it for a considerable time with iron scale in a closed receptacle, just as is done in the ordinary process of making malleable iron castings. Experiments were made by keeping an iron box filled with small fragments of German spiegeleisen packed in iron scale from the rolling mill at a red heat for some three weeks, when upon cooling it was found that the carbon was to a very large extent removed

without the oxydation of the manganese having taken place in any sensible degree, the chemical analyses of the substance before and after the process, made by Mr. J. Blodgett Britton, being as follows :

	Spiegeleisen before.	Spiegeleisen after.
Phosphorus	0.079	0.055
Manganese	11.636	10.689
Carbon	3.016	0.499

If the spiegeleisen had been granulated or cast in thin plates, or had it been of the quality rich in manganese such as is made at the West Cumberland Iron and Steel Works or the Société Anonyme des Hauts-Fourneaux de Marseilles, the results would no doubt have been even more favorable, but at all events they tend to show that the high-priced ferro-manganese is likely to find a much cheaper rival in such decarbonized spiegeleisen. The results have been published in the *Engineering and Mining Journal* of New York, for May 15, 1875.

American Bessemer Works and Rolling Mill Plant.—The following details of the Edgar Thomson Company, Limited, situated at Braddocks, eleven miles east of Pittsburgh, U. S., on the main line of the Pennsylvania Railroad, may be of interest as showing the modern arrangements of an American Bessemer steel works and rail mill, considered capable of turning out 200 tons of ingots and 225 tons of rails if rolled in double lengths, or 200 tons if in single lengths, per day of 24 hours.

The total surface area of the entire works is about 106 acres, and, besides being traversed by the Pennsylvania and the Baltimore and Ohio Railroads, has a frontage of 3,300 feet on the Monongahela River.

Buildings.—At present there have been erected :—Cupola house, 107 feet long, 44 feet wide, and 46 feet high ; converting house, 129 feet long, 84 feet wide, and 30 feet high ; blast engine house, 54 feet long, 48 feet wide, and 36 feet high ; boiler house, 178 feet long, 48 feet wide, and 18 feet high ; gas generator house, 90 feet long, 46 feet wide, and 26 feet high ; rail mill, 380 feet long, 100 feet wide, and 25 feet high, with a wing 100 feet long, 35 feet wide, and 17 feet high ; office and shop buildings, 200 feet long 60 feet wide, and 18 feet high ; and coal and iron store, 40 feet long, 20 feet wide, and 10 feet high. All these buildings have iron roofs, and are constructed wholly of brick except the generator house and rail mill, which have iron side columns with timber side framing.

The converting appliances comprise three cupolas each forty feet high and five feet internal diameter ; two 12 ton cupola ladles upon scales ; two 5 ton converters, fifteen feet high by six feet internal diameter ; twelve crane ladles for casting ; and a full supply of ingot moulds and flasks for bottom casting. Ample stove capacity is provided for drying the spare converter bottoms, flasks, and ladle stoppers. A crusher and mixing mill is in the cupola house, in which there is abundant room for storing the refractory materials intended for immediate use.

The steam machinery is worked by sixteen tubular boilers, each 5 feet diameter and 15 feet long with forty 4½-inch tubes, a separate grate 5½ feet wide by 7 feet long, and a separate chimney 2½ feet internal diameter by 75 feet high ; the boilers are fed by two duplex pumps, 10 inch by 5½ inch with 10 inch stroke, each having a direct cold water supply, and also a connection with either one of the two heaters, which are of the largest size, and supply the boilers with hot filtered water ; each boiler has an independent lined safety valve, feed valve, and blow off valve, and can be used or repaired independently of the others. For the converters, the two blowing machines have 42 inch cylinders with 4 feet stroke ; each has two 20 ton fly-wheels of 20 feet diameter, a balanced slide valve on the steam cylinder, and rubber faced poppet valves on the air cylinder ; the moving parts are balanced by an auxiliary piston in a small steam cylinder. A duplex engine is used for the cupolas with 18 inch steam cylinder, 60 inch air cylinder, and 3 feet stroke. A horizontal engine, 18 inch cylinder by 2 feet stroke, drives the crushing and grinding machinery. Another horizontal engine, 36 inch diameter of cylinder by 4 feet stroke, with a 50 ton fly wheel of 25 feet diameter, drives the blowing mill, whilst a similar engine 46 inch diameter by 4 feet stroke, drives the rail mill. A 3 ton steam hammer is used

for cutting the blooms and for any hot chipping needed; an engine, 16 inch cylinder by 12 inch stroke drives the rail saws, and another, of 18 inch by 2 feet stroke, the straightening presses, slotting machines, and drills for the fish-plate holes.

The hydraulic machinery comprises: —one duplex pressure pump with 25 inch steam cylinders, 9 inch water plungers and 2 feet stroke, and one pressure pump, 20 inch and 7¼ inch by 15 inch stroke; a complete distributing apparatus, all valves of which are connected to a common platform; two accumulators, 16½ inch diameter by 9 feet stroke; a ladle crane, 15½ inch diameter by 6 feet stroke; four cranes, 13 inch diameter by 9 feet stroke, of which three are for lifting ingots and one for the bottom casting flasks; two cylinders, 18 inches diameter by 9 feet stroke with racks and pinions for rotating the converters; one cylinder 12 inch diameter by 2 feet stroke, fixed on a car, for lifting and removing the bottoms of the converters; and two lifts, 9 inch diameter by 27 feet stroke, for raising materials in the cupola house.

The heating furnace plant includes twenty gas generators arranged in five blocks, a sheet iron cooling tube leading overhead to the brick gas flue, and six Siemens furnaces, each 8 feet wide by 20 feet long internal measurement, the chimneys being two in number, each 6 feet diameter by 98 feet high. Three of these furnaces have hydraulic machinery for charging the ingots as brought in red hot from the converting house, and also for drawing them for rolling mill plant. The ingots are bloomed in a 30 inch three-high mill, which is fitted with feeding rollers driven by an independent engine, and with hydraulic cylinders for moving the roller tables, for turning over the ingots, and for moving the middle roller to vary the sizes of the grooves as required. A "telegraph" leads to the steam hammer, and a steam crane piles up the ingots in the yard, whenever it is inconvenient to take them direct to the reheating furnaces for the roll-train. A 23 inch three-high train is used for rolling rails with three sets of rolls. A line of driven rollers leads to the saw carriage, and a second line of driven rollers to a 60 feet straightening plate. Space is provided for a swinging saw for cutting double length rails, and the hooks for handling the rails and rolls are provided with a power lifting apparatus to secure greater rapidity of working.

The water supply is brought from the river through 20-inch glazed sewer piping into a well at which two duplex pumps, each 20 inch by 7½ inch and 15 inch stroke are placed, and an 8 inch pipe from these pumps discharges into a 20,000 gallon tank from which supply pipes are laid on to the works.

A complete system of 30 inch gauge railway tracks go all round the works, and a store room, laboratory, and engineer's offices are to be found in the same building with the machine shop, which latter contains a 54 inch lathe for roll turning, one 30 inch and one 16 inch lathe, a 30 inch planing machine, two drills, a pipe a screw-cutting machine, all driven by an engine of 12 inch cutter and diameter by 18 inch stroke.

We may, in conclusion, mention that a short description, with plan and elevation of the blooming mill engine at these works, will be found in the number of *Engineering* for January 22d, 1875, p. 70, and in the number for March 12, p. 206, is given a plate and description of the Bessemer blooming engine.

Steel Rails Containing Phosphorus. —According to the *Moniteur Industrielle Belge*, the South Austrain Railway Company made in February an attempt at the manufacture of steel rails, by the employment of Terre-noire ferro-manganese, using for this purpose a mixture of pig iron and old rails from Styria which contained about one-six-thousandth part of phosphorus. The proportions actually used were: Praevalie pig iron 21, Praevalie old iron rails 24, Hermannshuette old iron rails 65, and Terre-noire ferro-manganese (containing 50 per cent. manganese) 2 per cent. of the whole. The resulting steel still contained 3½ thousandths part of phosphorus, but allowed itself to be rolled into rails with perfect ease. On this subject, a paper by M. Thiéblemont, the Engineer of the Saint Louis blast furnace, will be found in the *Bulletin de la Société Scientifique Industrielle de Marseilles*, vol. ii., p. 235, for 1874, entitled

"Le Fer et le Phosphore au point de vue Métallurgique;" and may be referred to as containing some interesting remarks.

CARBURATION OF IRON.—At the meeting of the Academie des Sciences, on the 5th April, M. Boussingault brought forward a communication on this subject in answer to the questions as to whether iron in the state of cast iron or steel is really in combination with the carbon, and in what proportions, or, in other words, what is the limit of carburation? The results of the most careful analyses show the amount of carbon in carburetted iron to be in variable proportions; thus steel may contain as low as one or two thousandths part, or from seven to ten thousandths, or as much as from ten to fifteen thousandths in hard steel. In cast iron the contents of carbon may vary from two to four per cent., and, exceptionally, even 5 per cent., but it is difficult to determine exactly how much, since the carbon is usually estimated in analyses by difference, and both cast iron and steel often contain manganese, silicon, phosphorus sulphur, and chromium, besides carbon; still the mean of the results gives 4.4 per cent. carbon in cast iron. If the pig iron is gray it is owing to its having, during its cooling, allowed the carbon to separate out in the state of graphite; but M. Boussingault, contrary to the generally received opinion, does not admit any sensible difference between the amount of carbon contained in white as compared with gray iron, and considers that, if any real combination between the iron and carbon is to be admitted, the proportion is as five equivalents of iron to one of carbon, and declares that, however high the temperature may be, there cannot enter more than five per cent. of carbon into the iron.

CARBON IN WHITE CAST IRON.—MM. Schuetzenberger and Bourgeois in the *Compt. Rend. de. l'Academie des Sciences* for April 5, 1875, communicate a paper on this subject. A quantity of white cast iron in coarse powder was treated with a solution of sulphate of copper precisely as in Ullgren's process for the determination of carbon in pig iron; the mixture of carbon with copper which resulted was then washed and treated in the cold with a moderately concentrated solution of perchloride of iron mixed with hydrochloric acid. The copper dissolved rapidly, and a black brown powder remained behind, which, after washing with hydrochloric acid and water, and drying at 100°, yielded on analyses:

Carbon	64.00
Water	26.10
Silicious ash	8.10
Matters not determined	1.80
	100.00

100 grammes of this white cast iron afforded by this method 7.135 of the dry black residue. The weight of the crystalline graphite amounted to 1.2 per cent. of this residue, and the determination of the combined carbon by Boussingault's method showed 63.1 per cent. carbon in the residue, and the sum of the combined carbon and graphite being 64.3, approaches very near to 64, the amount found by combustion. Deducting the silicon and other impurities, therefore, the authors conclude that the carbonaceous residue is in reality a hydrate of carbon; when heated to 250° it immediately loses its water without swelling up.

GAS ANALYSIS.—In *Frezenius Zeitschrift fur Analyt. Chemie*, 1875, p. 47, will be found a paper by Stoeckmann on the method of analyzing the gases from blast furnaces, generators, &c., in full detail; the main points of which consist in the combustion with oxyde of copper and determination of the carbonic acid and water so found; determination of the original carbonic acid by means of potash and soda lime; of the heavy carburetted hydrogens by sulphuric acid and combustion of the remaining gases (CO, C_2 H_4, H) and calculation of the several constituents; measuring the nitrogen, which, after the combustion with oxyde of copper, is collected unchanged. For details, however, we must refer to the original communication.

ESTIMATION OF SULPHUR IN COAL, COKE, &c.—*The American Chemist*, No. 8, for 1875, gives a process proposed by Mr. S. D. Hayes, the State Assayer for Massachusetts, for determining the amount of sulphur contained in coal, coke, pyrites, gunpowder, &c., as follows:—One gramme of the substance in fine powder is mixed with an equal quantity

of pure lime in a platinum crucible of about 9 centimetres diameter and 13 centimetres in height, and is brought to the consistence of paste by the addition of a sufficient quantity of distilled water, and constant stirring with a short glass rod, taking great care that every particle of the substance comes in contact with the lime solution. The crucible is now placed on a thick cast-iron plate over a Bunsen's gas-burner, and as soon as the mass is seen to be dry, it must be broken up to coarse powder and heated in a muffle to bright red heat for about twenty minutes, during which time all the carbon will be burnt away. The crucible is now allowed to cool, and then about 3 cubic centimetres of a concentrated solution of nitrate of ammonia is added, taking care not to add the solution too quickly, as loss might occur from the energetic action of the caustic lime on the ammonia salt. The whole mass is again heated to dryness and kept some five minutes at a red heat, is then allowed to cool, and dissolved in dilute hydrochloric acid, after which the sulphur in the solution can be determined in the ordinary manner by precipitation as sulphate of barium. A slight modification of this process is now much in use in the United States, which consists in adding to one gramme of the finely powdered substance, contained in a platinum crucible, about 4 or 5 times its bulk of a strong solution of pure soda in alcohol, and after a few minutes, adding, by degrees, 4 or 5 grammes pure slacked lime, stirring up the whole with a strong platinum wire until it has the consistence of paste, but adding no water, the rest of the process is the same as before described, except that sometimes nitrate of soda may be at once added, in which case the heating with nitrate of ammonia is not necessary.

THE PRIMING OF STEAM BOILERS.

From "The Engineer."

It is announced that the boilers of the Serapis on the voyage from Malta to Brindisi gave no trouble by priming, and that the ship attained a speed of thirteen knots. What steps have been taken to bring about this happy result we are unable to say. Possibly nothing was done, and this being the fact, we have the whimsical character, if we may use the words, of priming brought very prominently before us. We have already referred to the boilers of the Serapis; the whole subject of priming is, however, of sufficient importance to claim some further notice.

What in common language we call a steam engine, really consists of two machines—one for producing steam, the other for converting a part of its heat energy into mechanical power—and if we accept the statement that only one heat-unit in ten existing in the fuel is utilized as mechanical power, we must attribute a very large proportion of this enormous loss to that inefficient apparatus called a steam boiler. It is not probable that any very radical improvement in the engine itself lies hidden in the future, as all in fact that can be done by it is to deliver the steam or other gaseous matter after it has passed through the machine, at the lowest possible temperature, and by the simplest possible mechanical arrangements, or those which involve the least losses of heat by radiation, &c., and the minimum of useless work done in friction. The boiler, however, stands in a very different predicament; wasteful as it is in a high degree, even when in its best types and conditions—the causes of its waste are so patent that it is not so much for the philosopher as for the practical mechanic to devise the modes by which its wastefulness may be sensibly reduced without the introduction of cumbrous, inconvenient, or dangerous adjuncts; three points mainly being held in view, namely, that the fuel shall be perfectly burned to carbonic acid and water, that it shall be so burned without the introduction of a much larger volume of at-

mospheric air than is necessary to oxydize the fuel, and lastly, that the gaseous products of combustion shall pass away at a temperature not greatly exceeding that of the water in the boiler. There are other evils, however, belonging to existing forms of boilers, some of which are second only in importance to wastefulness; foremost amongst which are the danger of explosion, and the near cousin of this, the irregularity of action known as priming, to the last of which we confine our remarks here. We need not stop to describe in any general manner to our readers in what priming consists. Every one connected with the construction or working of boilers is but too familiar with the fact that the water within occasionally plays the most capricious pranks, part of it being forced in some more or less divided form and mixed with the steam, out of the boiler and into the engine. Beyond this bare description we fear it is not within the power of the best informed to give any more exact definition of this irregularity, accompanied by a lucid and complete explanation of the physical conditions which are essential to its production. It occurs with every known form of boiler worked with every sort of water, fresh or salt, and while in many cases it may be merely a nuisance unexpectedly and capriciously recurring, there are cases, more especially in marine boilers, in which its occurrence at all may be attended with the most disastrous results. Unexpected priming may cause a steamship to run upon a lee shore, or an ironclad to become unmanageable at the moment she is going into action, and, in the locomotive engine, may eventuate in delay or collision. We have had examples, comparatively recently, in the twinship Castalia obliging the remaking of her boilers, and still later in the troop ship Serapis, the priming of whose boilers seemed likely to mar the punctuality of the Prince of Wales' pageant in India.

Now it is a very remarkable fact that serious as are the inconveniences of this irregularity in the working of steam boilers, long as it has been known, and frequently as it is recorded as recurring both on land and at sea, almost nothing is as yet accurately known as to the physical conditions of which it is the result, and by consequence scarcely anything is prescribable scientifically for its remedy when it is found to occur. It is a branch of steam engineering which may be said to possess as yet no literature, and naturally so, for it has never yet received that searching and full investigation from the physicist which alone can rescue it from the state of confusion in which it is left by practical men, who, if they can manage to get rid of the immediate difficulty by any means, even though that be the substitution of a new boiler, are content, and care nothing about generalizing or even accurately recording the phenomena that have perplexed them. There is indeed no want of scattered communications on the subject to be found in mechanical journals, too often showing a puerile ignorance of what priming is, or how it is produced, and sometimes being the pseudo-scientific vehicle for advertising some nostrum which, being put into the boiler, shall relieve all its internal complaints. But amongst the treatises specially devoted to the construction and management of engines and boilers, whether published in English or French, nothing, so far as we know of, will be found giving us any exact and scientific information upon this not unimportant subject; the only English work that we can recall to memory which professes to treat the subject at all systematically is Armstrong's "Steam Engine Boilers," and his chapter of four or five pages only, gives no record of observed facts, which, when duly classified, must be the only solid basis for theoretic conclusions here as everywhere else, while the theoretic matter of which it does consist is little more than an unpleasant farrago of words without knowledge. What else can we say of an author who invokes J. Scott Russell and the theory of solitary waves of translation to explain the movements of the water within a common cylindrical boiler, having the fireplace at one end and the steam exit at the other, and imagines that out of the tumult of these waves a theory of priming can be extracted? The subject is incidentally treated also by Wilson in his more recent "Treatise on Steam Boilers," but although he avoids the pseudo theories of the first-named author, he has added little or nothing to

previous knowledge, and made no advance towards bringing the obscure phenomena of priming within the grasp of genuine science. Almost no experiments framed with scientific precision have been made upon the subject. Many years ago the well sunk through the sand at Camden Town Station, and intended to supply with water all the locomotive engines there, was found to yield a liquid which produced obstinate priming in the boilers. It was submitted for analysis to the late Master of the Mint, Dr. Graham, and also to the late Dr. Ure, and proved to contain free alkali—uncombined carbonate of soda—to the extent of about 1,160 grains in 100 gallons. Dr. Graham attributed the priming to its presence, and recommended the neutralizing the effect of the alkali by the addition of rather less than its equivalent of hydrochloric or sulphuric acid. This was tried in engines running to Watford and Berkhampstead, and with apparent success, but the experiments, of which some account will be found in the Minutes of the Institution of Civil Engineers, vol. viii., though apparently made under the superintendence of Mr. McConnell, were of a very incomplete and unsatisfactory description, and failed to throw any light upon why the presence of 11.6 grains of carbonate of soda to the gallon should produce priming, or why its conversion into sulphate of soda should prevent that. Indeed, how little real knowledge exists as to how this phenomenon is affected by the presence or absence of foreign matters in the water of the boiler is abundantly evident by the contradictory nostrums which have been recommended from time to time for the prevention of priming, or the contradictory causes which have been propounded as producing it. Thick and unequal incrustation, whether from sea or fresh water, has been assigned as a cause; while others have affirmed that new and perfectly clean boilers frequently prime badly, and yet lose this vice as incrustation gradually accumulates. Any film or coating of the interior of the boiler which interferes with perfect contact of the water has been held as a cause; while the internal coating of the plates with tallow has been held a protection for marine boilers against corrosion, and has not been supposed to produce priming, and the coating the interior with black lead, as well as the throwing of tallow and soap into the water, has been supposed to prevent priming; while, on the other hand a greasy condition of the interior of new locomotive boilers has been assigned as the cause of their priming, which has been also supposed to arise from the rapid steam-generating power attributed to the perfectly clean plates of new fire boxes. A number of other substances besides tallow, soap, &c., have at one time or another been declared panaceas for the malady, such as bran, chaff, horse dung, peat, "brewers' bottoms," angular pebbles, clay, &c., of all of which we can only say, on analogical grounds, that whatever admixture with the water may tend to facilitate the formation and escape of the steam bubbles formed at the heating surface of the boiler, *may* tend to diminish priming. That they can produce any other effect seems at least extremely doubtful.

A few, but very few, leading conditions tending to produce priming may be viewed as sufficiently—though as yet far from clearly or fully—known to warrant our making them the standpoint for experiment and research. Were the production of steam and its consumption by the engine perfectly equable, the supply of steam well within the limits of the boiler's power, and the rise of the steam from the water unimpeded, it would be difficult to see how priming should be possible. It is easy to see that steam may be generated so fast in proportion to the surface of separation of the steam from the water in a boiler, that its volume so far exceeds the means of escape that it must drive much of the water up bodily before it, just as in boiling water by applying heat to the end of a narrow glass tube the water is blown out by the violence of ebullition. This indicates that the "forced" working of a boiler is incompatible with immunity from priming, and that the first condition for preventing the latter is so amply to proportion the boiler, that the greatest volume of steam to be demanded of it shall be produceable without forcing, and by the passage of a fixed number of heat units per second through a unit of heating surface. Thus in the very large boilers used upon the Cornish

system with slow combustion, priming is almost unknown. The consumption of steam is, however, not equable. It is for an instant nothing at the change of stroke, and is not even equal in equal times during the stroke, or that portion of it before the steam is cut off. This involves inequalities in the tension of steam in the boiler keeping time with the stroke of the engine; and this inequality of tension again involves inequality in the rate of production and escape of the steam from the water. These inequalities are greater, other circumstances being the same, as the capacity of the cylinder is greater in proportion to the steam space in the boiler. A small bubble of steam in the act of forming at a heating surface of the boiler, and which would uniformly expand until its volume became sufficient for its detachment from the heating surface, and rise through the water, is by any reduction in the efflux of steam or increase of tension in the same, kept longer in contact with the heating surface, and when the tension is rapidly reduced it rushes upwards through the fluid with increased velocity, and may carry more or less of the water above its normal surface; and these phenomena will be more marked as the alternations of tension are more brusque and their range greater. And if the form and condition of the boiler be such that oscillations of the water thus originated can keep rhythmical time with the strokes of the engine or alternate cuttings off and emission of steam, the whole mass of water may surge at intervals far above its normal level, as carried up by the steam. We can thus see that, given the pressure at which the engine is to work, the capacity of the cylinder and that portion of it preceding the cut-off, and the piston velocity, we ought to be able to calculate for a given construction of boiler what must be the minimum steam space, such that the oscillations of tension within the boiler shall not reach the limit at which priming commences. But the foundation for any such calculation must consist in experiment made upon the large scale of actual work, and repeated for each distinct construction of boiler. For it is obvious that one of the conditions consists in the greater or less facility with which the steam as it is generated can escape from the water, and this will vary with the construction of the boiler, which may be such that from this cause alone priming may take place without reference to alternations of steam tension or insufficiency of steam space to bring those alternations within the necessary limits. These two conditions—which may be said to be purely dynamic, and are probably the most important that belong to this complex subject—can never be reduced to scientific law and practical rules except by an elaborate and costly train of experiments made upon boilers of working magnitude, and of the several types most necessary for the usual applications of steam power, as usually employed; and the object seems to be one of sufficiently wide importance to warrant the expenditure of public money upon them, both for the production of the necessary apparatus and for the payment of some one competent physicist, who, in conjunction with an equally competent mechanical engineer, should be entrusted with the experiments and with the discussion and publication of their results. That there are many subordinate conditions of a more or less purely physical, and so far obscure character—obscure, because as yet never accurately experimented upon and scientifically discussed—admits of no doubt, and they should also be investigated. Amongst these are differences in the state of the interior or evaporative surfaces, of foreign bodies in the water, whether in solution or in suspension; and these would comprehend a complete collection of the facts or supposed facts which are already on record, and their classification into the false and the true, with an elightened discussion of the latter. Why certain fluids within vessels of certain substances should always boil convulsively, which, though a fact well known, is as yet scarcely explained. Thus, sulphuric acid cannot be concentrated in glass vessels owing to this jumping at intervals, without risk; and platinum stills have been resorted to. Strong alkaline solutions jump in boiling in the same way, and several salts in solution produce like effects. At what degree of dilution with water these effects cease is not ascertained. But the primary facts requiring elucidation appear to be—what minimum

steam space must we have with a given type of boiler and given conditions of working, so that priming shall not be an inevitable mechanical necessity? We might add to the inquiry this—what modifications might advantageously be made in accepted types of boilers, so as to allow the freest possible extrication of the steam from the water? And in this part of the inquiry it would be necessary to take into account any movement communicated to the boiler itself. Thus, there can be little doubt that the great tendency to prime in cylindrical marine boilers is partly due to the increased oscillation of the water itself, which is caused powerfully to surge about by the form of these boilers and the movements of the vessel.

Our object has been here rather to direct attention to the importance of this problem, and to distinguish between the essential and the less important conditions involved in its solution, than to throw any new light upon the problem itself, which we believe can only be done by a large train of precedent experiments. Such experiments as are needed will never be made by the British Association, or other learned societies, committees, or other devices for the joint stock accumulation of knowledge, with nobody in particular responsible. If worthy of being made as a national object—which we hold such an experimental research to be—let it be conducted by some one or two well-remunerated men, responsible for the results which their prior reputations shall warrant, and with means and appliances provided from public sources, just as the laws of the relations between steam pressure and temperature which now govern the physicists and engineers of the world were experimentally ascertained by M. Regnault.

MODERN SANITARY SCIENCE—A CITY OF HEALTH.*

From "Nature."

It is my object to put forward a theoretical outline of a community so circumstanced and so maintained by the exercise of its own free will, guided by scientific knowledge, that in it the perfection of sanitary results will be approached, if not actually realized, in the co-existance of the lowest possible general mortality with the highest possible individual longevity. I shall try to show a working community in which death, if I may apply so common and expressive a phrase on so solemn a subject—in which death is kept as nearly as possible in its proper or natural place in the scheme of life.

Before I proceed to this task, it is right I should ask of the past what hope there is of any such advancement of human progress. For as my Lord of Verulam quaintly teaches, "The past ever deserves that men should stand upon it for awhile to see which way they should go, but when they have made up their minds they should hesitate no longer, but proceed with cheerfulness." For a moment, then, we will stand on the past.

From this vantage-ground we gather the fact, that onward with the simple progress of true civilization the value of life has increased. Ere yet the words "Sanitary Science" had been written; ere yet the heralds of that science, some of whom, in the persons of our illustrious colleagues Edwin Chadwick and William Farr, are with us in this place at this moment; ere yet these heralds had summoned the world to answer for its profligacy of life, the health and strength of mankind was undergoing improvement. One or two striking facts must be sufficient in the brief space at my disposal to demonstrate this truth. In England, from 1790 to 1810, Heberden calculated that the general mortality diminished one-fourth. In France, during the same period, the same favorable returns were made. The deaths in France, Berard calculated, were 1 in 30 in the year 1780,

* An address by Dr. B. W. Richardson, F. R. S., at the Brighton meeting of the Social Science Association.

and during the eight years from 1817 to 1828, 1 in 40, or a fourth less. In 1780, out of 100 new-born infants in France, 50 died in the two first years; in the latter period, extending from the time of the census that was taken in 1817 to 1827, only 38 of the same age died, an augmentation of infant life equal to 25 per cent. In 1780 as many as 55 per cent. died before reaching the age of ten years; in the later period 43, or about a fifth less. In 1780 only 21 persons per cent. attained the age of 50 years; in the later period 32, or eleven more, reached that term. In 1780 but 15 persons per cent. arrived at 60 years; in the later period 24 arrived at that age.

Side by side with these facts of the statist we detect other facts which show that in the progress of civilization the actual organic strength and build of the man and woman increases. Just as in the highest developments of the fine arts the sculptor and painter place before us the finest imaginative types of strength, grace, and beauty, so the silent artist, civilization, approaches nearer and nearer to perfection, and by evolution of form and mind develops what is practically a new order of physical and mental build. Peron—who first used, if he did not invent, the little instrument the dynamometer, or muscular strength measurer—subjected specimens of different stages of civilization to the test of his gauge, and discovered that the strength of the limbs of the natives of Van Dieman's Land and New Holland was as 50 degrees of power, whilst that of the Frenchmen was 69, and of the Englishmen 71. The same order of facts are maintained in respect to the size of body. The stalwart Englishman of to-day can neither get into the armor nor be placed in the sarcophagus of those sons of men who were accounted the heroes of the infantile life of the human world.

We discover, moreover, from our view of the past, that the developments of tenacity of life and of vital power have been comparatively rapid in their course when they have once commenced. There is nothing discoverable to us that would lead to the conception of a human civilization extending back over two hundred generations; and when in these generations we survey the actual effect of civilization—so fragmentary, and over-shadowed by persistent barbarism—in influencing disease and mortality, we are reduced to the observation of at most twelve generations, including our own, engaged indirectly or directly in the work of sanitary progress. During this comparatively brief period, the labor of which, until within a century, has had no systematic direction, the changes for good that have been effected are amongst the most startling of historical facts. Pestilences which decimated populations, and which, like the great plague of London, destroyed 7,165 people in a single week, have lost their virulence; jail fever has disappeared, and our jails, once each a plague spot, have become, by a strange perversion of civilization, the health spots of, at least, one kingdom. The term Black Death is heard no more; and ague, from which the London physician once made a fortune, is now a rare tax even on the skill of the hard worked Union Medical Officer.

From the study of the past we are warranted, then, in assuming that civilization, unaided by special scientific knowledge, reduces disease and lessens mortality, and that the hope of doing still more by systematic scientific art is fully justified.

I might hereupon proceed to my project straightway. I perceive, however, that it may be urged, that as mere civilizing influences can of themselves effect so much, they might safely be left to themselves to complete, through the necessity of their demands, the whole sanitary code. If this were so, a formula for a city of health were practically useless. The city would come without the special call for it.

I think it probable the city would come in the manner described, but how long it would be coming is hard to say, for whatever great results have followed civilization, the most that has occurred has been an unexpected, unexplained, and therefore uncertain arrest of the spread of the grand physical scourges of mankind. The phenomena have been suppressed, but the root of not one of them has been touched. Still in our midst are thousands of enfeebled human organisms which only are comparable

with the savage. Still are left amongst us the bases of every disease that, up to the present hour, has afflicted humanity.

The existing calendar of diseases, studied in connection with the classical history of them, written for us by the longest unbroken line of authorities in the world of letters, shows, in unmistakable language, that the imposition of every known malady of man is coeval with every phase of his recorded life on the planet. No malady, once originated, has ever actually died out; many remain as potent as ever. That wasting fatal scourge, pulmonary consumption, the same in character as when Cœlius Aurelianus gave it description; the cancer of to-day is the cancer known to Paulus Eginæta; the Black Death, though its name is gone, lingers in malignant typhus; the great plague of Athens is the modern great plague of England, scarlet fever; the dancing mania of the Middle Ages and convulsionary epidemic of Montmartre, subdued in its violence, is still to be seen in some American communities, and even at this hour in the New Forest of England; smallpox, when the blessed protection of vaccination is withdrawn, is the same virulent destroyer as it was when the Arabian Rhazes defined it; ague lurks yet in our own island, and, albeit, the physician is not enriched by it, is in no symptom changed from the ague that Celsus knew so well; cholera, in its modern representation, is a more terrible malady than its ancient type, in so far as we have knowledge of it from ancient learning; and even that fearful scourge, the great plague of Constantinople, the plague of hallucination and convulsion which raged in the fifth century of our era, has, in our time, under the new names of tetanoid fever and cerebro-spinal meningitis, been met with here and in France, and in Massachusetts has, in the year 1873, laid 747 victims in the dust.

I must cease these illustrations, though I could extend them fairly over the whole chapter of disease, past and present. Suffice it if I have proved the general proposition, that disease is now as it was in the beginning, except that in some examples of it it is less virulent; that the science for extinguishing any one disease has as yet to be learned; and that, as the bases of disease exist, untouched by civilization, so the danger is ever imminent, unless we specially provide against it; that the development of disease may occur with original virulence and fatality, and may at any moment be made active by accidental or systematic ignorance.

I now come to the design I have in hand. Mr. Chadwick has many times told us that he could build a city that would give any stated mortality, from fifty, or any number more, to five, or perhaps some number less, in the thousand annually. I believe Mr. Chadwick to be correct to the letter in this statement, and for that reason I have projected a city that shall show the lowest mortality.

I need not say no such city exists, and you must pardon me for drawing upon your imaginations as I describe it. Depicting nothing whatever but what is at this present moment easily possible, I shall strive to bring into ready and agreeable view a community not abundantly favored by natural resources, which, under the direction of the scientific knowledge acquired in the past two generations, has attained a vitality not perfectly natural, but approaching to that standard. In an artistic sense it would have been better to have chosen a small town or large village than a city for my description; but as the great mortality of states is resident in cities, it is practically better to take the larger and less favored community. If cities could be transformed, the rest would follow.

Our city, which may be named *Hygeia*, has the advantage of being a new foundation, but it is so built that existing cities might be largely modeled upon it.

The population of the city may be placed at 100,000, living in 20,000 houses, built on 4,000 acres of land—an average of twenty-five persons to an acre. This may be considered a large population for the space occupied, but, since the effect of density on vitality tells only determinately when it reaches a certain extreme degree, as in Liverpool and Glasgow, the estimate may be ventured.

The safety of the population of the city is provided for against density by the character of the houses, which ensure

an equal distribution of the population. Tall houses overshadowing the streets, and creating necessity for one entrance to several tenements, are nowhere permitted. In streets devoted to business, where the tradespeople require a place of mart or shop, the houses are four stories high, and in some of the western streets where the houses are separate, three and four storied buildings are erected; but on the whole it is found bad to exceed this range, and as each story is limited to 15 feet, no house is higher than 60 feet.

The substratum of the city is of two kinds. At its northern and highest part there is clay; at its southern and south-eastern gravel. Whatever disadvantages might spring in other places from a retention of water on a clay soil, is here met by the plan that is universally followed, of building every house on arches of solid brickwork. So, where in other towns there are areas, and kitchens, and servants' offices, there are here subways through which the air flows freely, and down the inclines of which all currents of water are carried away.

The acreage of our model city allows room for three wide main streets or boulevards, which run from east to west, and which are the main thoroughfares. Beneath each of these is a subway, a railway along which the heavy traffic of the city is carried on. The streets from north to south which cross the main thoroughfares at right angles, and the minor streets which run parallel, are all wide, and, owing to the lowness of the houses, are thoroughly ventilated, and in the day are filled with sunlight. They are planted on each side of the pathways with trees, and in many places with shrubs and evergreens. All the interspaces between the backs of houses are gardens. The churches, hospitals, theatres, banks, lecture-rooms, and other public buildings, as well as some private buildings such as warehouses and stables, stand alone, forming parts of streets, and occupying the position of several houses. They are surrounded with garden space, and add not only to the beauty but to the healthiness of the city. The large houses of the wealthy are situated in a similar manner.

The streets of the city are paved throughout in the same material. As yet wood pavement set in asphalt has been found the best. It is noiseless, cleanly and durable. Tramways are nowhere permitted, the system of underground railways being found amply sufficient for all purposes. The side pavements, which are everywhere ten feet wide, are of white or light gray stone. They have a slight incline towards the streets, and the streets have an incline from their centres towards the margins of the pavements.

From the circumstance that the houses of our model city are based on subways, there is no difficulty whatever in cleansing the streets, no more difficulty than is experienced in Paris. That disgrace to our modern civilization, the mud-cart, is not known, and even the necessity for Mr. E. H. Bayley's roadway movable tanks for mud sweepings (so much wanted in London and other towns similarly built) does not exist. The accumulation of mud and dirt in the streets is washed away every day through side openings into the subways, and is conveyed with the sewage to a destination apart from the city. Thus the streets everywhere are dry and clean, free alike of holes and open drains. Gutter children are an impossibility in a place where there are no gutters for their innocent delectation. Instead of the gutter, the poorest child has the garden; for the foul sight and smell of unwholesome garbage, he has flowers and green sward.

It will be seen, from what has been already told, that in this our model city there are no underground cellars, kitchens, or other caves, which, worse than those ancient British caves that Nottingham still can show the antiquarian as the once fastnesses of her savage children, are even now the loathsome residences of many millions of our domestic and industrial classes. There is not permitted to be one room underground. The living part of every house begins on the level of the street. The houses are built of a brick which has the following sanitary advantages:—It is glazed, and quite impermeable to water, so that during wet seasons the walls of the houses are not saturated with tons of water, as is the case with so many of our present residences. The bricks are perforated transversely, and at the end of each there is a wedge opening, into which no

mortar is inserted, and by which all the openings are allowed to communicate with each other. The walls are in this manner honeycombed, so that there is in them a constant body of common air let in by side openings in the outer wall, which air can be changed at pleasure, and, if required, can be heated from the fire-grates of the house. The bricks intended for the inside wall of the house, those which form the walls of the rooms, are glazed in different colors, according to the taste of the owner, and are laid so neatly that the after adornment of the walls is considered unnecessary, and, indeed, objectionable. By this means those most unhealthy parts of household accommodation, layers of mouldy paste and size, layers of poisonous paper, or layers of absorbing color stuff or distemper, are entirely done away with. The walls of the rooms can be made clean at any time by the simple use of water, and the ceilings, which are turned in light arches of thinner brick, or tile, colored to match the wall, are open to the same cleansing process. The color selected for the inner brickwork is gray, as a rule, that being most agreeable to the sense of sight; but various tastes prevail, and art so soon ministers to taste, that, in the houses of the wealthy, delightful patterns of work of Pompeian elegance are soon introduced.

As with the bricks, so with the mortar and the wood employed in building; they are rendered, as far as possible, free of moisture. Sea-sand containing salt, and wood that has been saturated with sea-water, two common commodities in badly-built houses, find no place in our modern city.

The most radical changes in the houses of our city are in the chimneys, the roofs, the kitchens, and their adjoining offices. The chimneys, arranged after the manner proposed by Mr. Spencer Wells, are all connected with central shafts, into which the smoke is drawn, and, after being passed through a gas furnace to destroy the free carbon, is discharged colorless into the open air. The city, therefore, at the expense of a small smoke rate, is free of raised chimneys and of the intolerable nuisance of smoke. The roofs of the houses are but slightly arched, and are indeed all but flat. They are covered either with asphalt, which experience, out of our supposed city, has proved to last long and to be easily repaired, or with flat tile. The roofs, barricaded round with iron palisade, tastefully painted, make excellent outdoor grounds for every house. In some instances flowers are cultivated on them.

The housewife must not be shocked when she hears that the kitchens of our model city, and all the kitchen offices, are immediately beneath these garden roofs; are, in fact, in the upper floor of the house instead of the lower. In every point of view, sanitary and economical, this arrangement succeeds admirably. The kitchen is lighted to perfection, so that all uncleanliness is at once detected. The smell which arises from cooking is never disseminated through the rooms of the house. In conveying the cooked food from the kitchen, in houses where there is no lift, the heavy-weighted dishes have to be conveyed down, the emptied and lighter dishes upstairs. The hot water from the kitchen boiler is distributed easily by conducting pipes into the lower rooms, so that in every room and bedroom hot and cold water can at all times be obtained for washing or cleaning purposes; and as on every floor there is a sink for receiving waste water, the carrying of heavy pails from floor to floor is not required. The scullery, which is by the side of the kitchen, is provided with a copper and all the appliances for laundry work; and when that is done at home, the open places on the roof above make an excellent drying ground.

In the wall of the scullery is the upper opening to the shaft of the dust-bin. This shaft, open to the air from the roof, extends to the bin under the basement of the house. A sliding door in the wall opens into the shaft to receive the dust, and this plan is carried out on every floor. The coal-bin is off the scullery, and is ventilated into the air through a shaft, also passing through the roof.

On the landing in the second or middle stories of the three-storied houses there is a bath-room, supplied with hot and cold water from the kitchen above. The floor of the kitchen and of all the upper stories is slightly raised in the centre, and is of smooth gray tile; the

floor of the bath-room is the same. In the living-rooms, where the floors are of wood, a true oak margin of floor extends two feet around each room. Over this no carpet is ever laid. It is kept bright and clean by the old-fashioned bees'-wax and turpentine, and the air is made fresh and ozonic by the process.

Considering that a third part of the life of man is, or should be, spent in sleep, great care is taken with the bedrooms, so that they shall be thoroughly lighted, roomy, and ventilated. Twelve hundred cubic feet of space is allowed for each sleeper, and from the sleeping apartments all unnecessary articles of furniture and of dress are rigorously excluded. Old clothes, old shoes, and other offensive articles of the same order are never permitted to have residence there. In most instances the rooms on the first floor are made the bedrooms, and the lower the living-rooms. In the larger houses bedrooms are carried out in the upper floor for the use of the domestics.

To facilitate communication between the kitchen and the entrance-hall, so that articles of food, fuel, and the like may be carried up, a shaft runs in the partition between two houses, and carries a basket lift in all houses that are above two stories high. Every heavy thing to and from the kitchen is thus carried up and down from floor to floor and from the top to the basement, and much unnecessary labor is thereby saved. In the two-storied houses the lift is unnecessary. A flight of outer steps leads to the upper or kitchen floor.

The warming and ventilation of the houses is carried out by a common and simple plan. The cheerfulness of the fire-side is not sacrificed ; there is still the open grate in every room, but at the back of the fire-stove there is an air-box or case which, distinct from the chimney, communicates by an opening with the outer air, and by another opening with the room. When the fire in the room heats the iron receptacle, fresh air is brought in from without, and is diffused into the room at the upper part on a plan similar to that devised by Capt. Galton.

As each house is complete within itself in all its arrangements, those disfigurements called back premises are not required. There is a wide space consequently between the back fronts of all houses, which space is, in every instance, turned into a garden square, kept in neat order, ornamented with flowers and trees, and furnished with playgrounds for children, young and old.

The houses being built on arched subways, great convenience exists for conveying sewage from, and for conducting water and gas into, the different domiciles. All pipes are conveyed along the subways, and enter each house from beneath. Thus the mains of the water-pipe and the mains of the gas are within instant control on the first floor of the building, and a leakage from either can be immediately prevented. The officers who supply the commodities of gas and water have admission to the sub-ways, and find it most easy and economical to keep all that is under their charge in perfect repair. The sewers of the houses run along the floors of the subways, and are built in brick. They empty into three cross main sewers. They are trapped for each house, and as the water supply is continuous, they are kept well flushed. In addition to the house flushings there are special openings into the sewers by which, at any time, under the direction of the sanitary officer, an independent flushing can be carried out. The sewers are ventilated into tall shafts from the mains by means of a pneumatic engine.

The water-closets in the houses are situated on the middle and basement floors. The continuous water supply flushes them without danger of charging the drinking water with gases emanating from the closet ; a danger so imminent in the present method of cisterns, which supply drinking as well as flushing water.

As we walk the streets of our model city, we notice first an absence of places for the public sale of spirituous liquors. Whether this be a voluntary purgation in goodly imitation of the National Temperance League, the effect of Sir Wilfred Lawson's Permissive Bill and most permissive wit and wisdom, or the work of the Good Templars, we need not stay to inquire. We look at the fact only. To this city, as to the town of St. Johnsbury, in Vermont, which Mr. Hepworth Dixon has so graphically de-

scribed, we may apply the description Mr. Dixon has written: "No bar, no dram shop, no saloon defiles the place. Nor is there a single gaming hell or house of ill-repute." Through all the workshops into which we pass, in whatever labor the men or women may be occupied—and the place is noted for its manufacturing industry — at whatever degree of heat or cold, strong drink is unknown. Practically, we are in a total abstainers' town, and a man seen intoxicated would be so avoided by the whole community, he would have no peace to remain.

And, as smoking and drinking go largely together, as the two practices were, indeed, original exchanges of social degradations between the civilized man and the savage, the savage getting very much the worst of the bargain, so the practices disappear largely together. Pipe and glass, cigar and sherry-cobbler, like the Siamese twins, who could only live connected, have both died in our model city. Tobacco, by far the most innocent partner of the firm, lived, as perhaps it deserved to do, a little the longest; but it passed away, and the tobacconist's counter, like the dram counter, has disappeared.

The streets of our city, though sufficiently filled with busy people, are comparatively silent. The subways relieve the heavy traffic, and the factories are all at short distances from the town, except those in which the work that is carried on is silent and free from nuisance. This brings me to speak of some of the public buildings which have relation to our present studies.

It has been found in our towns, generally, that men and women who are engaged in industrial callings, such as tailoring, shoemaking, dressmaking, lacework and the like, work at their own homes amongst their children. That this is a common cause of disease is well understood. I have myself seen the half-made riding-habit that was ultimately to clothe some wealthy damsel rejoicing in her morning ride, act as the coverlet of a poor tailor's child stricken with malignant scarlet-fever. These things must be in the ordinary course of events, under our present bad ordinary system. In the model city we have in our mind's eye, these dangers are met by the simple provision of workmen's offices or workrooms. In convenient parts of the town there are blocks of buildings, designed mainly after the manner of the houses, in which each workman can have a workroom on payment of a moderate sum per week. Here he may work as many hours as he pleases, but he may not transform the room into a home. Each block is under the charge of a superintendent, and also under the observation of the sanitary authorities. The family is thus separated from the work, and the working man is secured the same advantages as the lawyer, the merchant, the banker now possesses; or, to make the parallel more correct, he has the same advantage as the man or woman who works in a factory and goes home to eat and to sleep.

In most towns throughout the kingdom the laundry system is dangerous in the extreme. For anything the healthy householder knows, the clothes he and his children wear have been mixed before, during, and after the process of washing, with the clothes that have come from the bed or the body of some sufferer from a contagious malady. Some of the most fatal outbreaks of disease I have met with have been communicated in this manner. In our model community this danger is entirely avoided by the establishment of public laundries, under municipal direction. No person is obliged to send any article of clothing to be washed at the public laundry; but if he does not send there he must have the washing done at home. Private laundries that do not come under the inspection of the sanitary officer are absolutely forbidden. It is incumbent on all who send clothes to the public laundry from an infected house to state the fact. The clothes thus received are passed for special cleansing into the disinfecting rooms. They are specially washed, dried, and prepared for future wear. The laundries are placed in convenient positions, a little outside the town; they have extensive drying grounds, and, practically, they are worked so economically, that home-washing days, those invaders of domestic comfort, are abolished.

Passing along the main streets of the city we see in twenty places, equally distant, a separate building surrounded

by its own grounds—a model hospital for the sick. To make these institutions the best of their kind, no expense is spared. Several elements contribute to their success. They are small, and readily removable. The old idea of warehousing diseases on the largest possible scale, and of making it the boast of an institution that it contains so many hundred beds, is abandoned here. The old idea of building an institution so that it shall stand for centuries, like a Norman castle, but, unlike the castle, still retain its original character as a shelter for the afflicted, is abandoned. The still more absurd idea of building hospitals for the treatment of special organs of the body, as if the different organs could walk out of the body and present themselves for treatment, is also abandoned.

It will repay us a minute of time to look at one of these model hospitals. One is the *fac simile* of the other, and is devoted to the service of every five thousand of the population. Like every building in the place, it is erected on a subway. There is a wide central entrance, to which there is no ascent, and into which a carriage, cab, or ambulance can drive erect. On each side the gateway are the houses of the resident medical officer and of the matron. Passing down the centre, which is lofty and covered in with glass, we arrive at two side wings running right and left from the centre, and forming cross-corridors. These are the wards: twelve on one hand for male, twelve on the other for female patients. The cross-corridors are twelve feet wide and twenty feet high, and are roofed with glass. The corridor on each side is a framework of walls of glazed brick, arched over head, and divided into six segments. In each segment is a separate, light, elegant removable ward, constructed of glass and iron, twelve feet high, fourteen feet long, and ten feet wide. The cubic capacity of each ward is 1,680 feet. Each patient who is ill enough to require constant attendance has one of these wards entirely to himself, so that the injurious influences on the sick, which are created by mixing up, in one large room, the living and the dying; those who could sleep, were they at rest with those who cannot sleep because they are racked with pain; those who are too nervous or sensitive to move, or cough, or speak, lest they should disturb others; and those who do whatever pleases them; these bad influences are absent.

The wards are fitted up neatly and elegantly. At one end they open into the corridor, at the other towards a veranda which leads to a garden. In bright weather those sick, who even are confined to bed, can, under the direction of the doctor, be wheeled in their beds out into the gardens without leaving the level floor. The wards are warmed by a current of air made to circulate through them by the action of a steam engine, with which every hospital is supplied, and which performs such a number of useful purposes, that the wonder is how hospital management could go on without this assistance.

If at any time a ward becomes infectious, it is removed from its position, and replaced by a new ward. It is then taken to pieces, disinfected, and laid by ready to replace another that may require temporary ejection.

The hospital is supplied on each side with ordinary baths, hot-air baths, vapor baths, and saline baths.

A day sitting-room is attached to each wing, and every reasonable method is taken for engaging the minds of the sick in agreeable and harmless pastimes.

Two trained nurses attend to each corridor, and connected with the hospital is a school for nurses, under the direction of the medical superintendent and the matron. From this school nurses are provided for the town; they are not merely efficient for any duty in the vocation in which they are always engaged, either within the hospital or out of it, but from the care with which they attend to their own personal cleanliness, and the plan they pursue of changing every garment on leaving an infectious case, they fail to be the bearers of any communicable disease. To an hospital four medical officers are appointed, each of whom, therefore, has six resident patients under his care. The officers are called simply medical officers; the distinction, now altogether obsolete, between physicians and surgeons being discarded.

The hospital is brought, by an electrical wire, into communication with all

the fire-stations, factories, mills, theatres, and other important public places. It has an ambulance always ready to be sent out to bring any injured persons to the institution. The ambulance drives straight into the hospital, where a bed of the same height on silent wheels, so that it can be moved without vibration into a ward, receives the patient.

The kitchens, laundries, and laboratories are in a separate block at the back of the institution, but are connected with it by the central corridor. The kitchen and laundries are at the top of this building, the laboratories below. The disinfecting room is close to the engine-room, and superheated steam, which the engine supplies, is used for disinfection

The out-patient department, which is apart from the body of the hospital, resembles that of the Queen's Hospital, Birmingham: the first out-patient department, as far as I am aware, that ever deserved to be seen by a generous public. The patients waiting for advice are seated in a large hall, warmed at all seasons to a proper heat, lighted from the top through a glass roof, and perfectly ventilated. The infectious cases are separated carefully from the rest. The consulting rooms of the medical staff are comfortably fitted, the dispensary is thoroughly officered, and the order that prevails is so effective that a sick person, who is punctual to time, has never to wait.

The medical officers attached to the hospital in our model city are allowed to hold but one appointment at the same time, and that for a limited period. Thus every medical man in the city obtains the equal advantage of hospital practice, and the value of the best medical and surgical skill is fairly equalized through the whole community.

In addition to the hospital building is a separate block, furnished with wards, constructed in the same way as the general wards, for the reception of children suffering from any of the infectious diseases. These wards are so planned that the people, generally, send sick members of their own family into them for treatment, and pay for the privilege.

Supplementary to the hospital are certain other institutions of a kindred character. To check the terrible course of infantile mortality of other large cities —the 76 in the 1,000 of mortality under five years of age, homes for little children are abundant. In these the destitute young are carefully tended by intelligent nurses; and mothers, while following their daily callings, are enabled to leave their children under efficient care.

In a city from which that grand source of wild mirth, hopeless sorrow and confirmed madness, alcohol, has been expelled, it could hardly be expected that much insanity would be found. The few who are insane are placed in houses licensed as asylums, but not different in appearance to other houses in the city. Here they live, in small communities, under proper medical supervision, with their own gardens and pastimes.

The houses of the helpless and aged are, like the asylums, the same as the houses of the rest of the town. No large building for the poor of pretentious style uprears itself; no men badged and badgered as paupers walk the place. Those poor who are really, from physical causes, unable to work, are maintained in a manner showing that they possess yet the dignity of human kind; that, being worth preservation, they are therefore worthy of respectful tenderness. The rest, those who can work, are employed in useful labors which pay for their board. If they cannot find work, and are deserving, they may lodge in the house and earn their subsistence; or they may live from the house and receive pay for work done. If they will not work, they, as vagrants, find a home in prison, where they are compelled to share the common lot of mankind.

Our model city is of course well furnished with baths, swimming baths, Turkish baths, playgrounds, gymnasia, libraries, board schools, fine art schools, lecture halls, and places of instructive amusement. In every board school drill forms part of the programme. I need not dwell on these subjects, but must pass to the sanitary officers and offices.

There is in the city one principal sanitary officer, a duly qualified medical man elected by the Municipal Council, whose sole duty it is to watch over the sanitary welfare of the place. Under him as sanitary officers are all the medical men who form the poor-law medical

staff. To him these make their reports on vaccination and every matter of health pertaining to their respective districts; to him every registrar of births and deaths forwards copies of his registration returns; and to his office are sent, by the medical men generally, registered returns of the cases of sickness prevailing in the district. His inspectors likewise make careful returns of all the known prevailing diseases of the lower animals and of plants. To his office are forwarded, for examination and analysis, specimens of foods and drinks suspected to be adulterated, impure, or otherwise unfitted for use. For the conduction of these researches the sanitary superintendent is allowed a competent chemical staff. Thus, under this central supervision, every death and every disease of the living world in that district, and every assumable cause of disease, comes to light and is subjected, if need be, to inquiry.

At a distance from the town are the sanitary works, the sewage pumping works, the water and gas works, the slaughter-houses and the public laboratories. The sewage, which is brought from the town partly by its own flow and partly by pumping apparatus, is conveyed away to well-drained sewage farms belonging to the city, but at a distance from it, where it is utilized on Mr. Hope's plan.

The water supply, derived from a river which flows to the south-west of the city, is unpolluted by sewage or other refuse, is carefully filtered, is tested twice daily, and if found unsatisfactory is supplied through a reserve tank, in which it can be made to undergo further purification. It is carried through the city everywhere by iron pipes. Leaden pipes are forbidden.

In the sanitary establishment are disinfecting rooms, a mortuary, and ambulances for the conveyance of persons suffering from contagious disease. These are at all times open to the use of the public, subject to the few and simple rules of the management.

The gas, like the water, is submitted to regular analysis by the staff of the sanitary officer, and any fault he may detect which indicates a departure from the standard of purity framed by the Municipal Council is immediately remedied, both gas and water being exclusively under the control of the local authority.

The inspectors of the sanitary officer have under them a body of scavengers. These each day, in the early morning, pass through the various districts allotted to them, and remove all refuse in closed vans. Every portion of manure from stables, streets and yards, is in this way removed daily and transported to the city farms for utilization.

Two additional conveniences are supplied by the sanitary scientific work of this establishment. From steam-works steam is condensed, and a large supply of distilled water is obtained and preserved in a separate tank. This is conveyed by a small main into the city, and at a moderate cost distilled water can be supplied for those domestic purposes for which hard water is objectionable. The second sanitary convenience is a large ozone generator. By this apparatus ozone can be produced in any required quantity, and is made to play many useful purposes. It is passed through the drinking water in the reserve reservoir whenever the water shows excess of organic impurity, and it is conveyed into the city for diffusion into private houses for purposes of disinfection.

The slaughter-houses of the city are all public, and are separated by a distance of a quarter of a mile from the city. They are easily removable edifices, and are under the supervision of the sanitary staff. The Jewish system of inspecting every carcase that is killed is rigorously carried out, with this improvement, that the inspector is a man of scientific knowledge.

All animals used for food—cattle, fowls, swine, rabbits—are subjected to examination in the slaughter-house, or in the market, if they be brought into the city from other depots. The slaughter-houses are so constructed that the animals killed are relieved from the pain of death. They pass through a narcotic chamber, and are brought to the slaughterer oblivious of their fate. The slaughter-houses drain into the sewers of the city, and their complete purification daily, from all offal and refuse, is rigidly enforced.

The buildings, sheds and styes for

domestic food-producing animals, are removed a short distance from the city, and are also under the supervision of the sanitary officer; the food and water supplied for these animals comes equally with human food under proper inspection.

One other subject only remains to be noticed in connection with the arrangements of our model city, and that is the mode of the disposal of the dead. The questions of cremation and of burial in the earth have been considered, and there are some who advocate cremation. For various reasons the process of burial is still retained: firstly, because the cremation process is open to serious medico-legal objections; secondly, because, by the complete resolution of the body into its elementary and inodorous gases in the cremation furnace, that intervening chemical link between the organic and inorganic worlds, the ammonia, is destroyed, and the economy of nature is thereby dangerously disturbed; thirdly, because the natural tendencies of the people lead them still to the earth, as the most fitting resting-place into which, when lifeless, they should be drawn.

Thus the cemetery holds its place in our city, but in a form much modified from the ordinary cemetery. The burial ground is artificially made of a fine carboniferous earth. Vegetation of rapid growth is cultivated over it. The dead are placed in the earth from the bier, either in basket-work or simply in the shroud; and the monumental slab, instead of being set over or at the head or foot of a raised grave, is placed in a spacious covered hall or temple, and records simply the fact that the person commemorated was recommitted to earth in those grounds. In a few months, indeed, no monument would indicate the remains of any dead. In that rapidly-resolving soil the transformation of dust into dust is too perfect to leave a trace of residuum. The natural circle of transmutation is harmlessly completed, and the economy of nature conserved.

RESULTS.

Omitting, necessarily, many minor but yet important details, I close the description of the imaginary health city. I have yet to indicate what are the results that might be fairly predicted in respect to the disease and mortality presented under the conditions specified.

Two kinds of observation guide me in this essay: one derived from statistical and sanitary work, the other from experience, extended now over thirty years, of disease, its phenomena, its origins, its causes, its terminations.

I infer, then, that in our model city certain forms of disease, would find no possible home, or, at the worst, a home so transient as not to affect the mortality in any serious degree. The infantile diseases, infantile and remittent fevers, convulsions, diarrhœe, croup, marasmus, dysentery, would, I calculate, be almost unknown. Typhus and typhoid fevers and cholera could not, I believe, exist in the city except temporarily and by pure accident; small-pox would be kept under entire control; puerperal fever and hospital fever would probably cease altogether; rheumatic fever, induced by residence in damp houses, and the heart disease subsequent upon it, would be removed; death from privation and from puerpera and scurvy would certainly cease; delirium tremens, liver disease, alcoholic phthisis, alcoholic degeneration of kidney, and all the varied forms of paralysis, insanity, and other affections due to alcohol, would be completely effaced. The parasitic diseases arising from the introduction into the body, through food, of the larvæ of the entozoa, would cease, and that large class of deaths, from pulmonary consumption, induced in less-favored cities by exposure to impure air and badly-ventilated rooms, would, I believe, be reduced so as to bring down the mortality of this signally fatal malady one-third at least.

Some diseases, pre-eminently those which arise from uncontrollable causes, from sudden fluctuations of temperature, electrical storms, and similar great variations of nature, would remain as active as ever; and pneumonia, bronchitis, congestion of the lungs, and summer cholera would still hold their sway. Cancer, also, and allied constitutional diseases of strong hereditary character would yet, as far as we can see, prevail. I fear, moreover, it must be admitted that two or three of the epidemic diseases, notably scarlet fever, measles, and

whooping-cough, would assert themselves, and, though limited in their diffusion by the sanitary provisions for arresting their progress, would claim a considerable number of victims.

With these facts clearly in view, I must be careful not to claim for my model city more than it deserves ; but calculating the mortality which would be saved, and comparing the result with the mortality which now prevails in the most favored of our large English towns, I conclude that an average mortality of eight per thousand would be the maximum in the first generation living under this salutary *règime*. That in a succeeding generation Mr. Chadwick's estimate of a possible mortality of five per thousand would be realized, I have no reasonable doubt, since the almost unrecognized though potent influence of heredity in disease would immediately lessen in intensity, and the healthier parents would bring forth the healthier offspring.

As my voice ceases to dwell on this theme of a yet unknown city of health, do not, I pray you, wake as from a mere dream. The details of the city exist. They have been worked out by those pioneers of sanitary science, so many of whom surround me to-day, and specially by him whose hopeful thought has suggested my design. I am, therefore, but as a draughtsman, who, knowing somewhat your desires and aspirations, have drawn a plan, which you in your wisdom can modify, improve, perfect. In this I know we are of one mind, that though the ideal we all of us hold be never reached during our lives, we shall continue to work successfully for its realization. Utopia itself is but another word for time ; and some day the masses, who now heed us not, or smile incredulously at our proceedings, will awake to our conceptions. Then our knowledge, like light rapidly conveyed from one torch to another, will bury us in its brightness.

By swift degrees the love of Nature works
And warms the bosom, till at last sublim'd
To rapture and enthusiastic heat,
We feel the present Deity, and taste
The joy of God to see a happy world !

ON ROLLING-FRICTION.

By Professor OSBORNE REYNOLDS.

From the Proceedings of the Royal Society.

The motion of a roller or wheel on a surface is always attended with resistance. Coulomb made some experiments with wooden rollers on a wooden plane, from which he deduced two laws, viz. that the resistance is proportional to the weight of the roller, and inversely proportional to its diameter. These laws have since been found to apply to other substances, a different coefficient being used in each case. Beyond this, however, nothing appears hitherto to have been ascertained as regards the nature of this resistance to rolling. The source from which it springs does not appear to have been made the subject of investigation.

Some time ago it occurred to the author that it was probable that the deformation of the surface of the roller and of the plane, which must take place at the point of contact, would affect the distance which the roller would advance in turning through a certain angle. The pressure of the roller on the plane causes a certain temporary indentation and lateral extension in the latter, so that in passing from one point to another the roller does in truth pass over a greater extent of surface than the distance between these points. A simple experiment was sufficient to verify the truth of this conclusion. An iron roller 18 inches in circumference was found to roll through something like $\frac{3}{4}$ inch less than a yard in two complete revolutions when rolling on a plate of india-rubber. The softness of the india-rubber suffered the roller to indent it considerably ; and hence it might be expected that the ef-

fect would be much more apparent than when the roller was rolling on iron or any hard material. At the same time there is doubtless a certain amount of indentation in this latter case ; and this will probably cause a similar alteration in the distance rolled through, although too small to allow its being measured.

This falling off from what may be called the geometrical distance, suggested an explanation of the resistance to rolling, namely, that the extension of the surface or surfaces at the point of contact causes the one surface to slide over the other ; and this sliding is accomplished against friction. In this way we should expect to find the resistance to rolling greatest under those circumstances in which the sliding is greatest, *i. e.* where the indentation is greatest ; and so far it is in accordance with Coulomb's laws. In the case of india-rubber, we find the slipping is very large ; and hence we should expect the resistance to rolling to be large also ; and accordingly we find it so, for it is more than ten times as great as when the roller is on an iron plane. This very great resistance which india-rubber causes to rolling appears not to have previously caught attention ; and yet it is the natural explanation of the invariable failure which has attended the numerous endeavors which have been made to use this material for the tires of wheels.

This idea, that the resistance to rolling is due to the friction between the surfaces sliding at the point of contact, naturally leads to the conclusion that it must depend on the coefficient of friction between these surfaces, and that we might expect to diminish the resistance by using oil or any other means of reducing the coefficient of friction. This was the author's first impression. Experiments, however, showed that the effect of oiling the surface, although it did generally reduce the resistance, was very small ; and sometimes it appeared to act in the reverse manner, and increase the resistance. This conclusion or surmise was therefore wrong ; and the cause of the error was not far to seek. It consisted in having overlooked the fact that friction not only opposes the sliding of the one surface over the other, but also prevents it to a considerable extent, and thus modifies the deformation which would otherwise take place ; so that any diminution in the coefficient of friction is attended with an increase in the extent of slipping, which tends to balance the advantage gained by the reduced coefficient.

The truth of this view derives independent support from a circumstance remotely connected with rolling-friction, of which it furnishes an explanation. When the roller rests on a horizontal surface and is very slightly disturbed, it does not move off, but oscillates backwards and forwards. This happens on all kinds of elastic surfaces ; on soft india-rubber the oscillations are both large and continue for some time. Now if the deformation in the surface of the rubber were complete, there would be no tendency to bring the roller back ; but since, owing to friction, the india-rubber, under the advancing side of the roller, is prevented from extending while that under the other side is prevented from contracting, there will exist a state of constraint from which the surface is endeavoring to free itself by forcing the roller back.

Besides the relative softness of the materials, the curvature of the roller will affect the lateral extension both of the roller and the plane at the point of contact, so that if the roller and the plane were of the same material there would still be slipping. This would not be the case, however, between two wheels of the same diameter and material rolling in contact.

Such is a short sketch of the subject of the paper, a considerable part of which is devoted to the examination and illustration of the exact manner in which the deformation at the point of contact occurs, and the influence of friction upon it. The latter part of the paper contains an account of numerous experiments, and their results, which were undertaken as part of this investigation.

The first series of experiments relate to the resistance which an iron roller experiences on surfaces of different hardness. Cast iron, glass, brass, boxwood and india-rubber were tried. Extreme care was taken to make the roller and the surfaces true ; and this was so far successful that on cast iron the roller would roll in either direction when the

surface had an inclination of one in five thousand, or, roughly, a foot in a mile. Comparing the different surfaces, we see that the resistance increases with the softness, although apparently not in the simple proportion; on boxwood the resistance is nearly double as great as on the harder surfaces, and on india-rubber from six to ten times as great.

The second series of experiments were to ascertain the actual extent of slipping on india-rubber, both with a cast iron roller and also with an india-rubber tire glued on to the roller, and rolled on hard surfaces and on plates of india-rubber of different thicknesses.

These experiments bear out the arguments expressed in the first part of the paper; in fact the arguments were based on the experiments. There is no intention to imply that the whole of the resistance to rolling is in all cases due to the causes already mentioned. Under ordinary circumstances the irregularities of the surfaces and the crushing of the material beneath the roller are the chief causes. And, besides these, two other causes are discussed in the paper as having been brought to light by the experiment, viz. the communication of heat between the compressed material and that which surrounds it, which prevents the material immediately expanding to the same volume as it previously occupied, and the viscosity of the material, which also renders it slow to expand. Both these causes are, however, rather connected with the effect of the speed of the roller on the resistance than with the residual resistance, which, so far as the surfaces are perfectly true and perfectly hard, appears to be due to the friction which accompanies the deformation, and is hence called *rolling-friction*.

No attempt has yet been made to investigate the laws of rolling-friction, although the author hopes to continue the investigation in this direction as soon as he has obtained the necessary apparatus.

At the end of the paper attention is called to certain phenomena connected with railway-wheels, which it is thought now, for the first time, receive an explanation. Thus the surprising superiority of steel rails over iron in point of durability is explained as being due as much to the fact that their hardness prevents the wearing-action, *i. e.* the slipping, as that it enables them better to withstand the wear. Also the slipping beneath the wheel explains the wear of the rails in places where brakes are not applied; and the severe lateral extension beneath the wheel is thought to explain the scaling of wrought-iron rails.

LONG STROKE ENGINES.

From "The Engineer."

JAMES WATT, in the course of the not unsuccessful practice of his long life, almost invariably made his engines with a stroke equal in length to twice the diameter of the piston. The engineers, his contemporaries and immediate successors, followed his example very closely; indeed, it was not until the horizontal type of engine came into fashion that short strokes were extensively adopted, except perhaps in marine practice. There is good reason, we think, for believing that Watt was right in preferring long strokes; and that modern engineers are wrong in adopting strokes seldom greater than one and a-half times the diameter of the piston. A great deal may be urged in favor of a long stroke—very little can be said against it. Of course circumstances alter cases; and under peculiar conditions a long stroke cannot possibly be adopted. In dealing with ordinary stationary engines of the horizontal type, however, there is nothing dictated by conditions of space or weight which precludes the adoption of, within reasonable limits, any stroke we please; and we shall show that the arguments which can be urged in favor of long strokes are more weighty and powerful than any that can be urged against them. A

considerable source of loss in all engines is clearance. It is true that if the action of the valves be carefully adjusted to secure the given end, compression may be carried to just such a point at the termination of each stroke that all the vacant space between the piston and the valve will be filled with steam of the same pressure as that just entering from the boiler; but the cases in which this result is secured are not numerous, and it is very doubtful whether the disadvantages entailed by carrying the compression portion of the stroke far enough to secure the stated object do not overbalence the advantage obtained. It is at least certain that very few, if any, engines are worked with maximum economy in which the admission corner of the diagram is not tolerably square and well defined as a distinct angle and not as a curve. When steam is used very expansively, the loss due to clearance is in some measure reduced; but the weight of evidence goes to show that the smaller a clearance space can be made the better. Rankine has given, at pages 418, *et seq.*, of his treatise on the steam engine, an elaborate investigation of the effects of clearance and compression on the efficiency of a given weight of steam when used in an engine, and to this we must refer such of our readers as desire to go more fully into the question. It will suffice to state here that the investigation goes to prove that large clearance spaces are always a source of loss of power, if not of efficiency, even under the most favorable circumstances. It may, in a word, be assumed as granted that the smaller the clearance spaces in any engine the better. Now the amount of clearance may be taken as being, in all cases, a function of the diameter of the piston, and of it alone, because the safety space which must intervene between the piston and the cylinder lid at the termination of each stroke is almost a constant quantity for all engines, large and small. In a marine engine with a 100 in. cylinder $\frac{3}{4}$ in. clearance is ample, and as little as $\frac{1}{2}$ in. is not unusually met with. In a small engine, say, with a 25 in. or 30 in. cylinder, the distance allowed for clearance cannot be much less. If, then, the diameter of the piston determines the volume of the clearance space, it is evident that the smaller the piston for a given power the better. Thus, of two engines, one with a stroke of 6 ft. and the other with a stroke of 3 ft., the loss caused by clearance will be twice as great in the latter as in the former, other things being equal. It sometimes happens, however, that a single short slide valve only is used with long stroke engines. In such a case port space forms a considerable but illegitimate item in estimating clearance. But long stroke engines should always be worked with a valve at each end, by which means very short ports can be secured; there is no practical difficulty in the way, and we have consequently no right to saddle the long stroke engine with a defect which is introduced by the designer, and is in no way inherent in the type of engine.

A second point in favor of the long stroke engine, and one of much importance, is that the longer the stroke the smaller are the dead or unproductive strains to which the machine is exposed. Thus, with an engine having a 6 ft. stroke and piston 3 ft. in diameter, the strain on the crank pin, when it is at or about the dead point, will, with a total initial pressure of 80 lb., be 81,440 lb. An engine of the same power with a stroke of 3 ft., working under similar conditions of pressure and expansion, and number of revolutions, would exert a dead strain of 162,880 lb. Consequently, in the first place the frictional resistance of the journals and crank pin would be doubled; and, in the second place, they would be still further augmented by the fact that both the crank pin and the main bearing of the crank shaft would have to be of greater diameter than would suffice if the stroke were longer, not, be it understood, because the torsional strain on the crank shaft would be greater in one case than the other, but because the bending moment would be greater. We should then have at each dead point, and in fact throughout the whole stroke, not only a heavier pressure on the bearings, but that pressure would operate with a leverage augmented with the diameter of the shaft and the crank pin, and the *useful* work of the long stroke engine would consequently be greater than that of the short stroke engine. It is obvious that the framing, the piston, and many other

portions of the engine would also have to be made much more strongly than would be required with a long stroke. A third advantage proper to the long stroke is that the action of a steam jacket in securing economy is greater as the diameter of the cylinder is smaller. It is well known, indeed, that the jacket does little good when applied to large cylinders, its influence apparently not being able to extend far into a great body of steam. The condensing area of the piston—which is seldom jacketed—is also reduced by reducing the diameter. The fourth and last point that we shall at present urge in favor of the long stroke engine is that it is much easier to secure efficient action of the valve gear with it than with its short stroke rival.

Thus, if we cut off steam at one-sixth, in the case of the long stroke engine, the piston must, theoretically, move over a space of 1 ft. before the valve closes, while in the case of the short stroke engine the piston moves but 6 in. Now we may assume that the error in the action of the valves is constant for both engines, and that it amounts to a prolongation of the admission after the proper time to the extent of half an inch of piston stroke; that is to say, from the moment the expansion valve begins to close, until it is closed, the main piston will traverse half an inch, a proposition which presupposes much more efficient valve action than is often met with in practice. Under these circumstances the valve error would be twice as great in effect with the short stroke as with the long stroke engine. With the first it would represent $\frac{1}{12}$ of the whole stroke, with the second only $\frac{1}{24}$. If we bear in mind the effect produced by wear and tear, and vibration, and slack joints, on the best designed valve gear, it will be seen that the advantage possessed by a long stroke is of no mean importance; in fact, a valve gear which will give a very good diagram with a long stroke, may give a wretched card if the stroke of the engine to which it is applied be short. We may conclude our arguments in favor of long strokes by stating that they possess every advantage for working steam expansively with the maximum of economy, and that they entail the minimum amount of frictional resistance, so that not only is the indicated power to be obtained cheaply with them, but the greatest possible percentage of the indicated power is left available for useful purposes.

The only objections which we have ever heard urged against the long stroke engine are two in number. The first is that to obtain the proper number of revolutions the piston speed must be too high; and the second is, that long strokes require an extravagantly long engine if of the horizontal type, or too lofty an engine if the cylinder is vertical. The first point may, we think, be dismissed very speedily. There is no objection to a high piston speed. There is an objection to a rapidity of change in the direction of the strains on the crank pin, pistons, &c. While the piston of an engine of any length of stroke, and running at any velocity, is in mid stroke, there is no noise or jerking or knocking; it is only at the ends of the stroke that there is noise and trouble. If the long stroke engine does not make more revolutions than its rival, it will work as quietly, though with twice the piston speed. If the duration of the strains were always one way there would be no inconvenience in running at any speed we liked. The Brotherhood and Hardingham three-cylinder engine may be cited as an example; we have seen this engine driving a large silent fan at 500 revolutions a minute, and no sound could be heard except the whir of the steam escaping from the blast pipe.

As regards the second, the strains are materially reduced by the adoption of a long stroke; therefore it does not follow that the weight of a bed plate, &c., need be much, if at all augmented in anything like proportion to the increase in its length. But it does not follow that because we have a long stroke we must of necessity have a very long engine. For example, an engine with a three-feet stroke would be, if well proportioned, about 12 ft. 6 in. to 13 ft. long, allowing the connecting rod to be two strokes long. An engine with a six feet stroke, similarly proportioned, would be about 23 ft. over all. Now, in the first place, it has to be shown that there is any valid objection to this increased length, but, assuming for the sake of argument that there is, then the length admits of being reduced by making the connecting

rod shorter. The objection to a short connecting rod is, that it causes great wear of the cross-head and guides; but it is obvious that we reduce at once the strain on these members of the engine by one-half if we halve the area of the piston; and, in the next place, we double the extent of surface to be worn out, because the guides will be twice as long with the small piston as with the large. It appears, therefore, that, other things being equal, we may use a practically shorter connecting rod with a long stroke engine than would be admissible with a short stroke engine, and this being the case, if we cut down our connecting rod to one and a-half strokes length instead of retaining two strokes, the engine will be shortened to 20 ft. instead of remaining at 23 ft. This line of argument need only be applied to horizontal engines. We have already shown that with vertical cylinders, by adopting what is known as the "table engine," all objections connected with excessive height are overcome. The best proof that the expedient is satisfactory is supplied by the extended and successful use made of the table engine in driving screw propellers in the United States.

Marine engines are there used with strokes of 6 feet and 7 feet, where English engineers would hesitate to adopt anything in excess of 3 ft. We may add that there is evidence available of a tendency on the part of engineers in this country to adopt longer strokes than were in fashion a few years ago. We can assure such of our readers as are interested in steam engine construction that they will find, on examination, that it is worth while, in all cases, to adopt the longest stroke that can be obtained even with some sacrifice of time and trouble.

THE THERMO-ELECTRIC GENERATOR.

From the "Mining Journal."

CONSIDERABLE attention was directed some seven years since to an invention for generating electricity by heat, and although, as is usual with all new processes and apparatus, it was found in applying it practically that certain modifications of details were necessary, enough was done to show that the invention was worthy of development, and Mr. Charles Clamond, of Paris, has since succeeded in rendering it as near as may be perfect, thus solving the long-open problem of producing cheap electricity on a large scale. The principle involved in the original invention remains unchanged, but important alterations have been made in the construction of the bars and the method of applying the heat. The difficulties with regard to thermo-electric piles were at first very great, arising chiefly from the thermo-electric bars only retainig their power for a short time. Under the continued action of the heat, and the alternate successive heating and cooling to which the bars are subjected they acquire an interior resistance, which goes on increasing, (although the electric force is the same), and which eventually becomes such that the current engendered by the heat no longer gives more than a very feeble and inappreciable quantity of electricity. Sometimes there is even a complete cessation of the continuity, which renders the electric performance unreliable, perhaps at the moment when it is most required. After careful investigation Mr. Clamond discovered that this defect was was mainly owing to two causes—firstly, the surface of the metallic plate by contact with the metal or crystallized mineral oxydized and became a resistant to the passage; and, secondly, the crystallized bar, whether metallic or not, became split or cracked. These cracks, imperceptible to the naked eye, grew larger, and the oxydation penetrated to the interior of the bar, which became more and more resistant, which unfavorable circumstance rapidly rendered the pile useless.

By a special method of fastening or sealing the metallic plate in the part of the bar exposed to the heat, combined

with a peculiar method of casting the bars in hot moulds, Mr. Clamond succeeds in getting rid of the difficulties. When the thermo-electric pile is to be constructed he sometimes places all the bars in line, but generally he adopts the circular arrangement. A given number of elements are superposed and isolated one from another by mica or amianthus, forming by their superposition a cylinder, the interior of which has to be heated. A fire-clay tube, with perforations upon its circumference at intervals to form a kind of lengthened cap, is placed within the pile, an air space, open at the top, being left between the tube and the bars. The whole is heated with a Bunsen burner, ordinary coal gas supplied through a regulator being the fuel used. The mixture of the gas and air takes place in the refractory cap, and comes away at different heights through the orifices which lead into the annular space, where it is burnt in contact with the hot air coming from below, the previous heating of the air rendering the combustion very complete. The bars are also heated at the same time by the radiation of the fire-clay tube, which remains at a red heat, and by the contact of the flame and the products of combustion rising towards the chimney. Each bar is furnished with pole-plates for taking up or receiving the electric current. The method of uniting the plates to the electrode depends upon whether it is desired to develop a tension or a quantity current, and also upon the tension and upon the quantity of it. One of the plates may be sealed flatwise, as usual, to the cold end of the bar, the other being in contact with a bar in the interior or hot part.

In the moulding operation the metallic plate first placed in the moulds is provided with a little appendage, which, while the metal is flowing through or into the mould, will be sealed or fastened to the material of which the bar is composed. This appendage is a metallic ring soldered to the plate and formed in a plate somewhat narrower than the plate, or else it is taken even into a part of the plate, which is hallowed for the purpose, another portion being thrown back again and beaten down to double its thickness. The width of the ring should be smaller by about half than that of the plate, these plates, scraped or tinned, being placed in the mould and conveniently arranged. The metal or mineral envelops or surrounds the ring, which penetrates to the interior, constituting thus a core which forms one with the mass of the bar, and which insures an intimate and permanent contact between the plate and the bar. The material preferred for the bars is an alloy consisting of about two parts of antimony with one part zinc.

With regard to the efficient working of a thermo-electric pile, Mr. Clamond maintains that whatever be the substance employed, so long as it is cast in cold moulds it is impossible to prevent it cracking interiorly; that is due to the homogeneity of the crystalline covering, and in consequence of the inequality of the dilitation, which occasions the ruptures and crackings which take place in the bar. On contact with the cold sides or walls of the mould the exterior coating of the melted metal or mineral hardens quickly, and undergoes a kind of hardening which contracts it, while the interior of the bar is still liquid, and is congealed very slowly. It follows, as a natural consequence, that the crystallization is not uniform and regular. Mr. Clamond claims that his method entirely avoids these inconveniences; it consists in previously heating the moulds to a degree very near to the point of fusion of the metal or mineral. These latter, melted to a liquid in the crucible, are poured into the heated moulds, which are placed afterwards in a middle course, where they are allowed to cool slowly. He thus obtains bars which are perfectly homogeneous, and in consequence do not crack or split. For ensuring the proper arrangement of the elements of the pile he supports them between two ring-plates. These ring-plates are bound firmly to the central discs by arms traversed at their extremities by button-rods serving for cross bars. The inferior or lower plate is cast in a piece with the foot supports.

It will readily be understood that gas may not be at all times available for producing heat, but as Mr. Clamond has arranged for the use of coke, in that case the system would seem to be generally applicable. When he heats by coke for generating thermo-electricity

the coke is enclosed in a cylindrical column of iron concentric to the pile, and of a diameter narrower than the interior diameter in order to reserve an annular space between the two for the radiation of the heat. The coke rests upon a fixed or movable bar, which admits of the necessary air for the combustion, the products escaping by a lateral conduit to the chimney. The products can, however, be made to circulate in the space before passing away. To maintain the current continuously the coke (or where the pile is very small, charcoal) is charged at the top, and the residue can be removed by lowering the bars, which, by preference, are jointed.

The invention has already been fairly tested in this country, and the value and economy of the pile for telegraphic purposes have been placed beyond question by the result of many month's working at the Exchange Telegraph Company's office, in Bartholomew House. The Thermo-Electric Generator Company now propose to introduce it more generally, and as it is equally applicable to electro-plating and electrotyping, production of light—and, indeed, to all the various purposes for which batteries are commonly employed—there would appear to be a large field for business. At the recent meeting of the Société d'Encouragement pour l' Industrie Nationale the large gold medal was awarded to Mr. Clamond in recognition and appreciation of the value of his important discovery, and there can be no question that the honor was well deserved. The economy in maintenance is found to be very considerable in comparison with other batteries, and the current obtained is constant and free from polarization and exhaustion. By way of illustration of the efficiency of the pile, it may be stated that when employed for the deposition of metals it was found that a machine of 100 bars, with a consumption of 8 to 9 cubic feet of gas, would deposit about 1 oz. of silver per hour. The same apparatus, coupled for quantity, deposited about the same quantity of copper in a similar time. Another apparatus, with 400 bars, large, consuming 2 lbs. of coke per hour, will deposit about four times those quantities. The invention altogether appears to be a highly valuable one, and the progress made in introducing it will be watched with much interest.

NOTE ON THE DETERMINATION OF THE MAGNETIC MERIDIAN.

By L. WAGONER, C. E.

Written for Van Nostrand's Magazine.

Having occasion to determine the magnetic meridian in this place (Porto Alegre, Brazil), and finding a difference of twenty minutes in the results given by two good theodolites, I devised the following described magnetic apparatus, which, from its simplicity and cheapness, can be made useful in many cases:

The magnet or needle is composed of ten pieces of watch spring 100^{mm} long (3.93 in.), 3^{mm} broad, and 0.3^{mm} high, each piece was magnetized separately, and then the ten were bound together with silk thread at each end; upon the north pole was secured a small silver frame carrying a mirror four-tenths of an inch square. It will be seen that the magnet when completed has a section that is nearly square, and each side is 3^{mm} ($\frac{1}{8}$ in.). The magnet is suspended in a small ring; in the upper part of this ring is a steel pivot upon which the whole swings freely; the lower side of the ring has two small flat pieces, $\frac{1}{2}$ inch long, soldered upon it to keep the magnet from falling out of the ring. The whole is enclosed in a small wooden box with glass ends, and in the middle of the box is a small cross piece of wood carrying a narrow piece of glass about one-tenth inch broad, and one-half inch long. This piece of glass is parallel to the axis of the box, and the pivot in the ring rests upon the flat surface of the

glass. The mirror is made approximately correct by bending the silver frame until the plane of the mirror is perpendicular to the axis of the magnet, which can be proved with a square or triangle. To use it, set it up in the magnetic meridian and balance the needle in the ring by sliding from one end to the other until it remains level; then look in the mirror, and going backwards a few feet, look for the reflected image of your eye, at the same time by reason of the mirrors being very small you can look on beyond it; there in the line place a flag pole. The magnet is then turned upon each of the remaining three sides, and a similar reading made for each—the mean of the four is the magnetic meridian. But for greater exactness it is better to place the instrument about ten feet from a theodolite, and as nearly in the magnetic meridian as possible, about one foot in front of the theodolite and one foot higher than the telescope. Secure a piece of plank two feet long at right angle to line of sight; this plank is to carry a plumb bob having a cord one-sixteen inch well chalked, so that it may be easily seen; then focus the telescope for double distance of the mirror, and slide the plumb along the board until its reflected image coincides with the cross wires and mark its place; repeat this operation with the other three sides of the magnet in order to eliminate any error in the mirror, and mark the mean of the four readings; then determine the point upon the wood where the cross wires would strike, and also the distance from the mirror to the wooden cross piece; from this data the angle can be found that the axis of the telescope makes with the magnetic meridian. Thus, suppose the distance from mirror to the wood = 100 inches, the difference of the four readings from the line of sight = 2 in., then the angle $= \frac{2}{200} = \frac{1}{100}$ $= 0° 35'$. The magnet in my apparatus with mirror and ring weighs 82 grains, and has a supporting power of five times its weight. The pivot is a small steel screw ground to angle upon its point of 60° and made very hard. With the telescope a variation of five seconds can easily be seen. The entire cost of the apparatus was about seven dollars.

THE RESOURCES OF EGYPT.

From "Engineering."

We are frequently reproached as a nation with our indifference to Indian affairs, and not without reason, for the average Englishman probably acquires his smattering of Indian knowledge at school and forgets it subsequently along with his mathematics and Greek. Such a change could not be sustained against us as regards Egypt, for there are few countries so well known to Englishmen of all ranks and ages. The height of the Nile even is the subject of numerous telegrams to the London press, but who would care to learn the height of the Sone or Tungabudra, or even know to what rivers those euphonious names apply? The recent unreasoning panic in Egyptian affairs is, therefore, more a matter of surprise than it would otherwise have been, and affords another proof that knowledge apparently sound and extensive is often vague and shallow. The natural wealth and exceptional physical advantages of Egypt have many times been urged by the friends of the country during the recent panic, but until the letter of Mr. Fowler appeared in the *Times* of the 28th ult., no specific facts were adduced which would enable an investor to put an approximate money value to the future resources of Egypt. The required information came the more appropriately from an engineer, since the Khedive himself has adopted an engineering policy in the development of his country, and according to Mr. Fowler arranges with him as his consulting engineer the general scope and leading details of works to be carried out, and provides for a proper competition between the leading manufacturers of the chief European nations.

Mr. Fowler takes a sanguine view of the future resources of Egypt, and al-

though he carefully abstains from imposing his views upon investors he nevertheless submits certain facts, within his own knowledge to their consideration. He points out firstly that a large proportion of the debt of Egypt is due to the construction of gigantic works such as the Suez Canal and Alexandria Harbor, which though not immediately profitable in the commercial sense of the word, were essential to national development—works in short corresponding to the making of roads, the drainage, and other costly preliminary operations, which an ordinary proprietor would undertake for the development of his estate. Further, Mr. Fowler calls attention to the fact that all works of this character required in Egypt are now practically complete and paid for, and that the future expenditure can be restricted to such works as will yield immediate and adequate returns. Improved means of irrigation is evidently in Mr. Fowler's opinion the present requirement of Egypt and the source of its future increased welfare. From recent surveys and investigations Mr. Fowler has been led to the conclusion that 600,000 acres of desert land may be easily and profitably brought under cultivation, and he states that the annual value of the crops on these lands would probably range from 8*l.* to 12*l.* per acre. Again, with a proper system of irrigation the manual labor at present expended in raising water for the lands—the money value of which is equivalent to no less than one-half the crops—would be almost entirely dispensed with. A gradual increase of revenue from the land tax of several millions per annum is thus indicated, and the elevation in the status of the Fellaheen from drawers of water to cultivators of the soil, and the enrichment of all Egyptians, would also follow. It will be interesting to see how far these sanguine anticipations of the Khedive's engineer are justified by the facts.

Egypt is an essentially agricultural country, and in proportion to the area of the land under cultivation, it is rather more densely populated than the United Kingdom. Last year the area under cultivation was at the rate of a little more than one acre per head of population in the United Kingdom, whilst in Egypt with a population of about one-sixth the acreage was rather less than one per head. The relative productiveness of the land of the two countries is, of course, beyond comparison in favor of Fgypt. In our own country ordinary pasture land constitutes a large proportion of the whole, whilst in Egypt not a piece of turf is to be found unless perhaps in the Esbekieh, or in some of the Palace Gardens. With soil so rich that a heavy crop of Indian corn, and another of wheat, or eight crops of clover may be raised from the same land in a year, a broad expanse of park land is a luxury not to be indulged in.

Perhaps nothing strikes the traveler more on his first visit to Egypt than the thick sprinkling of people which he finds uniformly extending over the whole surface of the country. In England we may travel by rail through hundreds of miles of country, and unless it be in harvest or haymaking time, see nothing more than an occasional ploughman with his team, or a solitary rustic, acting as a scarecrow to the birds—the only other animated things to be seen. In Egypt, on the contrary, there is a perpetual harvest, and the country "creeps" with people, but the whole of this fertile and populous land would be nothing more than a burnt-up desert, but for one cause, and that is the presence of the Nile.

The extent of the cultivated land is limited only by the line up to which the Nile water travels by inundation canals or otherwise. Those who have passed through the Suez Canal may remember the blossoming little gardens a few feet square at some of the "stations" which look as distinct and independent of the surrounding desert as if the whole garden were simply an extra large box of flowers brought over direct from France in some vessel for the benefit of an expatriated Frenchman. Had our travelers landed they would have found the first cause of these oases on the desert banks of a salt water canal in a little lead pipe, perhaps not one inch in diameter, communicating with a miniature watercourse, in its turn communicating with a small sweet water canal, and had they followed up this canal they would have found, after a journey of 120 miles, that it was the Nile itself which had

transformed the little patch of desert land into a garden.

The same is true of the whole of Egypt. A sharp line as distinct as the color on a map marks the boundary between the bright green of the cultivated land and the sparkling yellow sands of the desert, and the same line serves to mark the limit of the inundation of the Nile. The fertilizing properties of the water are due, says Dr. Letheby, to the notable quantity of ammonia and nitrogenous organic matter contained in solution and to the large amount of sedimentary matters charged with phosphates. There is no other source of water in Egypt than the Nile, for the well waters are simply Nile water robbed of the chief portions of its fertilizing properties and objectionally charged with saline aliments abstracted from the soil. Nile water is at all times turbid, but to a varying degree. At Low Nile the solid matters in suspension amount to but 5 grains per gallon, whilst at High Nile the proportion is 105 grains, or about double the percentage of solids found in average London sewage. The quality of Nile water, therefore, is all that can be desired, but in forming an estimate of the future resources of Egypt, or in other words of the increased productiveness and the extension of area of the cultivated land, it is necessary to be satisfied that there is sufficient water in the river for irrigation purposes, and that it can be conveyed to the desired points.

In June, 1873, the velocity and sectional area of the Nile when at its lowest was measured in a very exact manner, and the results showed a minimum discharge of 12,600 cubic feet per second. The river rarely falls so low as it did in 1873, and the minimum discharge in all years applies but to a few days. Thus a fortnight after the preceding measurements were taken the discharge was found to have more than trebled, and it continued rapidly increasing until the maximum for the year of about 270,000 cubic feet per second was reached. A reference to the statistics of our leading Indian canals will satisfy any one interested that there is an ample supply of water in the Nile at all times of the year for the complete irrigation of all the cultivated lands of Egypt, and of all probable or possible additions to these lands. We must now see how the water is to be got to the land with the least expenditure of labor.

The general fall of the Nile Valley and of the river itself is at the rate of about 5 inch per mile, and the land falls from the river bank towards the desert at the same inclination. A more rapid fall would in some respects have been advantageous, but as the ground is even and easy of excavation, the general conditions are extremely favorable for irrigation works. The level of the land immediately contiguous to the river is about 20 feet above Low Nile, or 3 feet below a good average High Nile. The actual rise of the Nile varies considerably year by year from the 23 feet assumed above. Thus the High Nile of 1868, which was the lowest for many years past, rose but 19 feet, whilst on the other hand the alarmingly high Nile of 1874, rose no less than 28 feet. It is difficult to say which extreme is the most undesirable. When the Nile does not rise to the required height the crops are burnt up, and the land is unproductive over a great extent of country. When the Nile is too high, the water infiltrates through the soil, washes up the salts, and poisons the vegetation, thus involving not merely a loss of the year's crops, but much work to clear the soil for the next year's sowing. During last year's High Nile tens of thousands of men were for some time engaged in raising the river banks, but though the direct overflow of the Nile was thus successfully frustrated, the process of infiltration went on unchecked, and many valuable crops were destroyed.

The irrigation works at present in operation in Egypt may be roughly comprised under two heads, viz., Canals Selfi and Canals Nili, corresponding respectively to the perennial and inundation canals of our Indian nomenclature. In the former canals the depth of water is about 3 feet at lowest Nile, in the latter the depth of excavation is only from 12 feet to 15 feet, and, therefore, the bottom is far above Low Nile. The headworks consist generally of a substantial barrage or brick viaduct with openings from 10 feet to 15 feet wide, closable by vertical planks or sheet piling. At intervals down the canals similar barrages

are placed, by closing which the level of water is raised to a sufficient extent in some instances to inundate adjoining lands, and in others to materially reduce the height to which the water has to be raised by manual labor or otherwise. This system involves considerable work in clearing the canals periodically of sedimentary deposits, which had the flow been constant, would have been carried on to the lands inundated, to the great advantage of the latter. Great improvements have been effected by His Highness the Khedive, and the extension of the irrrigation canals alone have, Mr. Fowler states, involved the excavation of 65 per cent. more material than the whole of the Suez Canal. Still in the summer season water is not only scarce but what there is of it has to be raised by sakiehs, or primitive chain pumps worked by buffaloes, by shadoofs, or the still more primitive bucket and balance-beam system, and when the lift is very small by the altoway, which is nothing more than a simple basket swung backwards and forwards by a couple of men. Cornish pumping engines are also to be found on the banks of the Nile. But centrifugal pumps driven by portable engines are far more common. Whichever system of raising water may be in use the cost is a most serious tax upon the land. As a consequence, between May and July much of the land lies fallow, for the ground is too hard to be plowed without previous inundation. From want of water during these months some of the villages are occasionally in a bankrupt state, unable to pay the Government taxes or to obtain necessaries. The whole scene is, however, at once transformed upon the appearance of a portable engine and centrifugal pump, the proprietor of which will perhaps graciously accept one-third or one-half of the produce in return for watering the land three times.

The ordinary charge for watering once is at the rate of 20 francs per feddan, or acre, for land situated close to the pumping station, and as much as 40 francs for land four or five miles distant. It is stated that the loss from infiltration and evaporation renders the last sum the least favorable bargain to the proprietor of the pump. When the water is raised by means of the shadoof each feddan requires the services of two men for about one hundred days, assuming the crop to be doora sefi, or the summer growth of Indian corn.

It will be apparent enough that there is room for a considerable addition to the resources of Egypt, if at the present time from £3 to £6 per acre is expended in watering, which in India would cost but as many shillings in the districts where high level canals have been constructed. All that is required in Egypt is a constant supply of water to the main canals at the same height, and in the same quantity as obtains when the Nile has risen from 12 feet to 15 feet. The measured flow in the Menoufieh Canal, which has a bottom width of 200 feet, with its headworks placed at the apex of the Delta, was but 360 cubic feet per second in June of last year, and no less than 6,300 cubic feet two months later. The minimum flow in this canal should not be less than 4,000 cubic feet per second, which quantity could be well spared from the Nile when at its lowest, and if the level of the water in the river at the intake of the canal could be raised about 14 feet the required quantity would flow down the canal at a sufficient height to irrigate almost the whole of the lands without pumping. The same remark applies to the main canals having their intake at the same part of the river, and irrigating the lands on the right and left banks of the Damietta and Rosetta branches respectively. It was with a view to obtain this desideratum that the grand barrage of the Nile was projected and constructed.

This work may be shortly described as a couple of massively constructed brick viaducts carried across the two branches of the river, and including between them 132 arches or openings of about 16 feet span, the said openings being closeable by iron sluices of somewhat peculiar construction. It was originally intended to back up the water by this structure about 15 feet, but owing to defective foundations it has not been deemed prudent to submit the barrage to a greater stress than that due to a head of 3 feet to 5 feet of water. If the barrage could be completed in an efficient manner the problem of improved irrigation would be to a great extent

solved. The extension and enlargement of a few canals would be all the additional work required to supersede the greater proportion of the costly pumping now going on, and to reclaim a large additional amount of land from the desert.

Our space only admits of a very brief reference to the nature, rotation, and value of the crops grown in Egypt. To illustrate these matters we will cite as an example the practice on an actual estate in the Delta, exactly 1000 acres in extent. This, as regards farming operations, is usually dealt with in three portions, the first of which, 300 acres in extent, is sown with cotton in April, and about nine months subsequently with berseem, or clover. The second portion, 350 acres in area, is sown with doora, or Indian corn, in July, and with wheat or barley about three months afterwards. The remaining 350 acres is for a part of the year under clover and for a certain time fallow. The number of waterings the above crops receive in the year varies from two to eight, and the total is equivalent to a single watering of 6750 acres. It is stated on good local authority that the required supply involves the constant working day and night of a 12 inch centrifugal pump delivering nominally 2000 gallons per minute. Probably five inches in depth would be an ample allowance for each watering, and this, without reckoning waste, would be provided for by an average discharge of 1500 gallons per minute. Upon no less good local authority it is stated that the value of the above crops when raised would average from £12 to £13 per acre.

The facts and figures advanced in the present article will be sufficient to prove that the present produce of the land in Egypt is no measure of her future resources, but that by judiciously designed and economically executed irrigation works, the profitable returns of the land under cultivation may, in many instances, be doubled; whilst an addition, amounting to no mean percentage of the total area of the land may by the same means be reclaimed from the desert.

BAIE VERTE CANAL.

By THOS. GUERIN, C. E.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

In the month of September, 1874, I contributed an article to this Magazine on the subject of the "Baie Verte Canal." I find that in the "Transactions of the American Society of Civil Engineers," Second Series, No. 21, there is published a paper contributed by "Clemens Herschel, C. E., Member of the Society," on the same subject. Mr. Herschel commences by asserting that my article "is founded on a gross hydraulic heresy," and then proceeds as follows:

"The first part of the present discussion, which is to prove Mr. Guerin wrong was not difficult; the second part, to show what is the correct solution of his problem, required more time," &c.

"Mr. Guerin's article would be an excellent one were not the very basis of it an illusion. I allude to the assumption that $v = n \sqrt[3]{r}$, where n is a coefficient by Mr. Guerin supposed to be somewhat uniform; r is the vertical rise of a tidal stream during any length of time t, and v is its mean horizontal velocity during the same time. From two experiments, Mr. Guerin deduces $n = 1.3313$ and 1.3124," &c.

"To test the above enunciated 'principle,' therefore, I have taken data given in Beardmore's Manual of Hydrology relative to the tidal phenomena of the Clyde, those given in Hagen's Wasserhaum, Vol. iii., page 161, relative to the tide of the Weser; and, finally, those to be found in the Annals des Ponts et Chausses, 1861, in an article by M. Partiot on the Seine.

"The following are the results compared with the two values of n already given:

"On the Missignash, 1.3313 and 1.3124;

on the Clyde, opposite Glasgow, 34.685; Clyde Bank, 65.407; Bowling, 116.82, and Port Glasgow, 90.03; on the Weser opposite Flagshalger Siel, 2.504, and on the Seine, 3.612.

"It thus appears that n is not constant for the different parts of the same river nor for any two rivers. In fact there is no such law as $v=n\sqrt[3]{r}$ in tidal streams, for the rise and flow of the tide are far more a matter of the propagation of waves than of flow in a channel."

That is how Mr. Herschel has proved "Mr. Guerin" wrong.

I will now show how unwarrantable the assertions made in the above quotations are, and how erroneous his paper is from end to end. Furthermore, I will show that the authorities he quotes, instead of aiding his views, confirm the conclusions arrived at in the article of mine already referred to.

In the first place, the formula $v=n\sqrt[3]{r}$ is not "an assumption," it is the result of investigation. I have assumed nothing; nor have I asserted anything without demonstrating it.

Again, I have not asserted that "r in the formula is the vertical rise of a tidal stream during any length of time t, and v is its horizontal velocity during the same time." If Mr. Herschel looks again at the investigation he will find that, in arriving at the above formula, the time is a unit, and in finding the value of $n=1.3313$, that unit is one hour.

It can be seen by reading the article, that this value for n is not intended to apply to all rivers nor to "different parts of the same river," if those parts are, themselves, different.

It can be seen that the coefficient sought was obtained for the current of a tide flowing in an even horizontal bed. The River Missiguash was selected for the experiment, at a place about one and a half miles from the sea-shore, and the time selected was at a stage of the tide when it was rising nearly uniformly. The river was in the immediate vicinity of the proposed canal; its bed was reasonably even, and it was shown in the investigation that the inclination of the river was such that it could not affect the velocity of the tidal current so as to make it differ perceptibly from that on a horizontal plane.

The coefficient obtained for the Missiguash cannot materially differ from that obtained for a similar river, and must be reasonably correct for obtaining the velocity of a tidal current flowing in an even horizontal bed such as the summit reach of the Baie Verte Canal; if there is any truth in science. I did not then, nor do I now claim extreme accuracy for this coefficient, and I have therefore suggested to other gentlemen to experiment and verify or amend it if necessary.

Mr. Herschel comes forward, and instead of attempting to verify or correct the value of n under the necessary conditions, has recourse to the tides of the River Clyde as recorded in Beardmore's Manual of Hydrology, and says that the application of the above equation would give those values for n which I have already quoted from his paper. He should have shown how he obtained those values.

Although I do not claim extreme accuracy for the coefficient 1.3313 nor assert its applicability to different rivers; yet, I hold that there is not a tidal river in existence that will give those coefficients which Mr. Herschel states he has obtained for the Clyde from Beardmore's Hydrology.

Now for facts. Beardmore's Manual of Hydrology, to which Mr. Herschel refers as authority, is now before me, and on examining what is stated there respecting the tides of the River Clyde, I find in page 253 that the mean velocity of the flood stream above New Shot Isle is 78.10 feet per minute, and the average velocity below New Shot Isle is 38.56 feet per minute. It must be borne in mind that above New Shot Isle comprises Glasgow and Clyde Bank, while Bowling and Port Glasgow are below.

Referring to the same page of the same book, I find the following statement in reference to the tidal range and duration of flood. The values of r and n, as given on the following page, are computed from this data, and inserted by myself thereunder:

Spring Tides.	Glasgow.	Clyde Bank.	Bowling.	Port Glasgow.
Tidal range.....	8 ft. 4″	8 ft. 0″	8 ft. 9″	10 ft. 0″
Duration of flood.....	5 h. 10 m.	5 h. 15 m.	5 h. 24 m.	6 h. 6 m.
Value of r.....	1.612	1.524	1.620	1.707
n.....	0.550	0.558	1.110	1.090
Neap Tides.				
Tidal range.....	6 ft. 3″	5 ft. 10″	5 ft. 11″	6 ft 1″
Duration of flood.....	5 h. 14 m.	5 h. 43 m.	5 h. 52 m.	6 h. 26 m.
Value of r	1.194	1.020	1.008	0.945
n.....	0.605	0.630	1.298	1.327

It is necessary to remark here that at the end of Beardmore's Manual of Hydrology there is plate XI. giving a section of the bottom of the River Clyde between Glasgow and Port Glasgow. This section shows the bottom of the Clyde to be of a most jagged description from Glasgow to a point about one mile distant from Bowling. At Bowling it is comparatively even for about two miles. At Port Glasgow the river is fifty feet deep and upwards, so that a tidal current cannot be much interfered with by any irregularities in the bottom.

On examining the values of n in the above table, it can be seen that at Glasgow and Clyde Bank, where the bottom is uneven, $n=0.550$ and 0.558 respectively for spring tides; while at Bowling and Port Glasgow, where the bottom is not so irregular, the values of n are 1.110 and 1.090 respectively. Again, for Neap tides the values of the coefficient n at Glasgow and Clyde Bank are 0.605 and 0.630 respectively; while at Bowling and Port Glasgow the values are 1.298 and 1.327.

From these facts it can be seen that the values of the coefficient n for the River Clyde, at Bowling and Port Glasgow, differ but little from that obtained for the Missiguash; in fact, they are singularly coincident. At spring tides there seems to be a difference of $\frac{1}{10}$ between the Clyde and the Missiguash; but this may have arisen from some extraneous cause, such as a strong wind which often blows at the time of spring tides; or it may have arisen from the mode of observation.

The authorities, "Hagen's Waserbaum" and "The article by M. Partiot on the Seine," I have not at my command; but there is an extract from M. Partiot's article given in Beardmore's Manual of Hydrology (page 267 to 270), where probably Mr. Herschel has sought the information he refers to. Although this extract seems to contain all the observations recorded in the article, yet there is not the proper data in it from which to find the value of n. The only place where an approach to the data even in a loose way can be found is at Quillebeouf; and here, with even such imperfect data, the value of n will be found to differ from that obtained for the Missiguash by a fraction varying from $\frac{55}{100}$ to $\frac{67}{100}$.

If, in the face of such facts as these, Mr. Herschel is still of the opinion that the coefficients for the River Clyde, Seine, &c., are those extraordinary numbers given in his paper, I do not feel bound to take the trouble of dissuading him; but when he attacks an article of mine, using those numbers as his only basis for attack, and publishes to the engineering profession that a formula deduced by me from a mathematical investigation "is wrong" and "is a delusion," then I must correct him.

Admitting that those extraordinary numbers of his had been correctly obtained, it would even then be a matter of great assurance to assert that there is no such law as $v=n\sqrt[3]{r}$, deduced as it was from a mathematical investigation. It should have been shown that the investigation was erroneous before such a sweeping assertion was published among scientific papers.

This gentleman, on having disposed of my article to his own satisfaction, next undertakes "to show what is the correct solution of the problem." He commences with the subject of the propaga-

tion of waves, and at once appeals to a written work by "D'Arcy and Bazin sur la propagation des ondes." He refers to some experiments made by M. Bazin, and in a note* at the bottom of the page he states he does not propose to quote from J. Scott Russell's experiments; nor from the data given in Beardmore's Manual of Hydrology; nor from the purely theoretical paper of the Astronomer Royal, Mr. Airy, though, he says, they all contain much that is of interest.† He further says, he hardly knows whether it will be needful to give proofs of the correctness of the theory of wave propagation, and of the applicability of the same to the case of the Baie Verte Canal. He says: "On the whole it will perhaps be sufficient to refer to the works already cited together with, say David Stevenson's Canal and River Engineering."

Mr. Herschel is manifestly of the opinion that those authorities confirm his belief, that the filling of the Baie Verte Canal from tide water depends on the propagation of a wave. I will refer to those authorities presently, but, first, I must state what is well known to Hydraulic Engineers, that the propagation or velocity of a wave has no connection whatever with the flow or forward advancement of water. When a wave moves in water, there is no current of water accompanying the wave as a consequence of the wave's velocity or propagation. If the wave made by a steamboat moving in a canal or river be observed, it will be seen that, although the wave is moving at a high velocity, yet, if it meet any floating body, such as a piece of wood, the latter is not borne along with the wave; it is simply lifted up; the wave passes under it and the piece of wood is deposited in the spot where it was met at first by the wave. A wave is simply a protuberance moving through the water. The characteristic of a wave is that energy, not matter is transferred in its propagation (see Chamber's Encyclopædia). There is no relation whatever between the propagation or velocity of a tidal wave and that of a tidal current.

In corroboration of what has been just affirmed, I will refer to David Stevenson, to whom reference has been also made by Mr. Herschel.

Mr. Stevenson states in his "Canal and River Engineering" (pages 59 and 60) "But the passage of the tidal wave through an estuary or river must not be mistaken for what is called the tide current, which is a totally different phenomenon." He then states that the tidal wave passes through Dornoch Firth at the rate of 22 miles per hour; but the current flows through the same place with a velocity not exceeding four or five miles an hour.

He further says: "The laws of propagation of the tidal wave to which we first alluded, depends as explained on circumstances somewhat obscure; but the velocity of the tide current, or that current which flows into our rivers and affects the transit of shipping, is due entirely to the slope or fall on the surface of the water. The amount of this slope has been shown to be dependent on the rapidity with which the tide rises, and the amount of obstruction presented to its propagation up the river. The more rapid the rise of the tide and the greater the obstructions to its flow, the higher will the tide wave, at certain parts of a river or estuary be heaped up. A head of water is thus formed whose height is due to the rapidity of the rise of the tide and the obstructions to its progress, and a flow of water having a velocity due to that head is generated up the river or estuary, and this flow of water is what we term the tide current."

A similar explanation to the above is given in my previous article to this Magazine; but in more concise terms. I had not read Mr. Stevenson's explanation before I wrote that article. The conclusions were deduced from actual observation of the phenomena of the tide in the Bay of Fundy while I was engaged by the Canadian Government in surveying the line of the proposed Baie Verte Canal.

Referring to Beardmore's Manual of Hydrology, to which reference is made by Mr. Herschel on the subject of wave propagation, the following statements are made in pages 251 and 253 respecting the tidal wave and tidal stream of the Clyde:

* *Vid.* Transactions of the American Society of Civil Engineers, page 187.
† *Ibid.* Page 188.

	Velocity of wave per minute.	Velocity of stream per minute.
Between Port Glasgow and Bombay.....	1080 ft.	78 ft.
Between Bowling and Clyde Bank.....	584 ft.	78 ft.
Between Clyde Bank and Glasgow.....	1441 ft.	38 ft.

In page 265, River Severn :

	Wave per minute.	Stream.
Between Newnham and Framlode.....	1907 ft.	217 ft.
Page 268, River Seine....	1274 ft.	332 ft.

To adduce an example nearer home—the speed of the tidal wave in Chesapeake Bay, from Cape Henry to the head of the Bay is 15 miles an hour, while the tidal current moves at the rate only of one mile an hour.

On reading the above quotations, taken from the authorities referred to, respecting those observed phenomena ; it is manifest there is no relation existing between the velocity of a tidal wave and that of a tidal current or stream. This conclusion is also deducible from the formulæ investigated by Professor Airy, the Astronomer Royal.

The formulæ of Professor Airy are founded, first, on the equation of continuity, which is deduced from the hypothesis of equality existing between a rectangular parallelopiped of water at rest and the oblique parallelopiped formed in disturbed water by the new positions of the light particles constituting the angular points of the former parallelopiped. But as the water is supposed to be in a rectangular canal, the extent of the parallelopiped in the direction of the breadth of the canal is supposed to be constant ; therefore it is sufficient to assume the equality of the parallelograms which form a side of each in the direction of the length of the canal.

The canal being of uniform depth, the equation will be as follows :

$$Y=\int\frac{dX}{dx}$$

(This expression being integrated between O and Y.)

An equation is next found for the pressure on any particle from the forces that act upon it. The equation is expressed as follows :

$$-\frac{d^2y}{dt}=\frac{dP}{dy'}+g$$

Where P is the pressure in every direction on the lower part of a disturbed molecule of water in consequence of the weight of the filament of particles above it.

y' or $y+Y$ is the vertical coordinate of the particle.

dt is the increment of time in which the vertical coordinate becomes $y'+\delta y'$.

g denotes the force of gravity.

This equation is integrated between the limits for the bottom of the molecule and the top of the wave, and there results the hydrostatic force by which a vertical filament descends or moves horizontally. If all extraneous forces, such as the attraction of the sun or moon, on a molecule be represented by F, the equation of motion becomes

$$\frac{d^2X}{dt^2}=F-\frac{dP}{dx}$$

This equation gives a relation between the terms X, Y, x, y, t.

In order to represent oscillatory motion, both the horizontal and vertical displacements are represented by terms containing the sines or cosines of angles depending on the time t.

Let it be assumed that

$$X=R\cos(nt-mx)+S\sin(nt-mx).$$

R and S being functions of y.

Suppose that gravity is constant, and that no extraneous forces act, and that for the present there is retained only the first power of $\frac{dX}{dx}$.

The above equations give

$$\frac{d^2X}{dy^2}+\frac{d^2X}{dx^2}=0$$

From these equations are obtained the values of X and Y in terms of A $\cos(nt-mx)$ and B $\sin(nt-mx)$.

These values will not be altered if mx is increased or diminished by a whole circumference, that is, if x is increased or dimnished by $\frac{2\pi}{m}$, $\frac{4\pi}{m}$, &c., while t remains constant. Hence $\frac{2\pi}{m}$ is the value of the increments of x which correspond to points where the particles of water are in the same condition with respect to disturb-

ance, that is, $\frac{2\pi}{m}$ is the length of a wave.

By similar reasoning $\frac{2\pi}{n}$ is the period of a wave or the time of two successive formations of a wave summit at the same place. Hence $\frac{n}{m}$ is the velocity of the wave; and from the value found for it by the theory, it follows that the velocity depends on m and on the depth of water; the latter being constant, the velocity depends on the length of the wave; or it depends on the time in which a particle of water makes a complete vibration. If the length of a wave or the time of vibration is given, the velocity will vary with the depth of water.

The foregoing is a brief synopsis of the mode of reasoning pursued by Professor Airy in his paper on "Tides and Waves." Its applicability to the motion of a stream or current of water is apparent.

From these formulæ it is deduced that when the length of the wave is not less than one thousand times the depth of the water the velocity of the wave is equal to $\sqrt{g\,h}$, where g denotes gravity and h the depth of water. Mr. John Scott Russell confirms this formula in his report pursuant to the inquiries made by the British Association.

More generally: if

v=the velocity of a wave;

h=the depth of disturbance of the particles of water;

g=gravity.

There will result:

$v=\sqrt{g\,h}$ even in water of unlimited depth.

$v=\sqrt{\frac{g\,L}{2\pi}}$ is the velocity of a rolling wave in deep water, when L= length of the wave, and π=ratio of circumference to diameter.

From these facts, it is evident there is no analogy or relation existing between the velocity of a current or stream and that of a wave of any description.

Mr. Herschel, in quoting from Bazin's work, says: "If U represent the velocity of the water in the canal behind the wave that is requisite for the delivery of Q, that is, if $U=\frac{Q}{W\,H}$; then when $U>\sqrt{2\,g\,H}$ the wave will break up, or, as M. Baron expresses it, 'deferlement' will take place."

It is evident that here M. Bazin is misunderstood by Mr. Herschel, for the reason that no man of the ability of M. Bazin would state such foolish doctrine. "Deferlement" will take place or the wave will break up, when the first portion of the wave is overtaken by the succeeding portion, or "the water in the canal behind the wave," as Mr. Herschel expresses it. It will be remembered that the velocity of the wave is $\sqrt{g\,H}$, hence U will only require to be greater than this quantity in order to overtake the wave in front and cause it to break up. The wave will, therefore, break up and "deferlement" will take place long before $U>\sqrt{2\,g\,H}$. But it appears Mr. Herschel thinks otherwise.

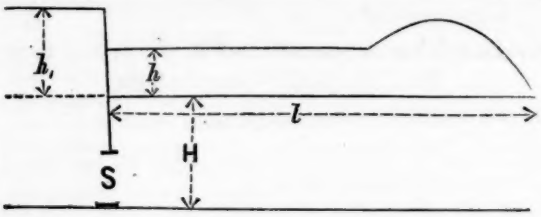
He states he has made three experiments on the Northern Canal at Lowel, in order to ascertain whether the wave gets away fast enough to allow the proper quantity, which would flow through the submerged orifice or sluice of a lock gate to enter the canal. He says the experiments were a test of formulæ and principles already established.

I shall leave the reader to appreciate the motive for which those experiments were made.

The next and final portion of his paper is devoted to the investigation of formulæ for the filling of a canal from tide water.

I shall copy what he says, and I shall number his equations for the sake of reference:

"Take now the case of the Northern Canal in my experiments, or that of the Au Lac Reservoir and Baie Verte Canal. Let H be the depth of the canal when the gates are opened; h the depth of the water above the original level in the canal at any time at which on the outside the water stands h_1 feet above the original canal level, and l the distance which the first wave has traveled since the gates were opened. The problem is to find the value of h and l; having given H, h_1, the effective area S of the



submerged orifice and the width w of the canal.

Approximately

$$l = t\sqrt{g\,H} = t\,v \quad . \quad . \quad 1°$$

$$h = \frac{Q}{w\,v} \quad . \quad . \quad . \quad . \quad 2°$$

$$Q = S\sqrt{2\,g}\,\sqrt{h_1 - h} \quad . \quad 3°$$

$$Q = S\sqrt{2\,g}\,\sqrt{h_1 - \frac{Q}{w\,v}} \quad . \quad 4°$$

$$Q = \sqrt{2\,g\,s^2\,h_1 + \left(\frac{g\,s^2}{w\,v}\right)^2} - \frac{g\,s^2}{w\,v} \quad 5°"$$

Although there is no mention made of Q in the above notation, it is evident he intends it to represent the quantity of water which enters the canal through the orifice S in one second.

The velocity of a wave traversing the canal is $\sqrt{g\,H}$, and this quantity is designated by v (see equation 1°).

From an inspection of the above figure, it is evident that it is allowed that the quantity Q entering the canal through the orifice S increases the depth by h, and flows along the surface of the water in the canal thus generating a current.

Equation 2° contains two errors—one arises from the fact that in it, the canal is assumed to be rectangular, when in reality the sides have a slope of one in two. The second error arises from the fact that in this equation, the velocity of the current generated by Q is assumed to be the same as the velocity of the tidal wave or v: two quantities which have been shown to have no relation whatever.

Equation 3° is erroneous; it should be as follows:

$$Q = m\,S\,\sqrt{2\,g\,(h_1 - h)}$$

where m is the coefficient of discharge through an orifice, which can be found in all treatises on hydraulics.

Equation 4° contains all the errors already pointed out.

Equation 5° contains all the previous errors—this is the formula by which he has made his computations.

There are numerous errors in his paper besides these pointed out here.

A mind of ordinary intelligence can see at a glance that his formula is erroneous without going to the trouble of analyzing his paper as I have done. Suppose that in the spring of the year, when navigation is about to be opened, the summit reach of this canal will then require to be filled. At that time there is no water in it, and the height denoted by H is equal to zero. His equation 2° has $h = \frac{Q}{w\,v}$ where $v = \sqrt{g\,H}$. It follows from this that h is infinitely great; or, in other words, as soon as the water would be let into the canal in the spring, a flood or wave higher than the distance from here to the star Arcturus would rush into the canal as soon as the gate is opened if his formula were true.

The application of his formula to the Baie Verte Canal, based as it is on such error and absurdity, renders every column after the first, erroneous in page 198 of the "Transactions of the American Society of Civil Engineers."

It is almost needless to remark that the figure above, which is copied from Mr. Herschel's paper, gives a false representation of the phenomena that take place during the tidal flow into the canal.

I shall not further discuss Mr. Herschel's paper; but I must say that, considering the apparent industry he has evinced in his attempt at acquiring means by which to attack what I have written in this Magazine, one would almost feel sorry for the fate his exertions have met with here.

The conclusions arrived at in my article of September, 1874, remain unchanged.

ON THE CONDITIONS AND PROSPECTS OF ARCHITECTURE IN THE UNITED STATES.

By WM. FOGERTY, Fellow of the Royal Institute of British Architects.

The importance of travel to the professor or student of architecture is a matter pretty extensively recognized and admitted. Even before the days of steamships and railways, it was considered an essential part of every English architect's education that he should spend a year or more on the continent of Europe, visiting the noble monuments of ancient, mediæval, and modern art to be found there. But, notwithstanding the great facilities of travel alluded to, which have brought America practically as near to us as France or Germany were but a few years since, that continent has not commonly been looked on as by any means a desirable field for similar travel. It has been too generally assumed that there was nothing to be seen or learnt of the art in America, an error which I trust this paper may have some effect in exploding, while at the same time I may be able to point out the peculiar attraction America presents, as being undoubtedly the grandest field the world has ever presented for architectural practice, calculated to awaken the noblest ambition in the breast of every true lover of his art; an ambition too, not by any means likely to be disappointed in those who, having become duly qualified by European study, may not find suitable openings at home, and may choose to transfer the scene of their labors to the New World.

In this latter respect America, and especially the United States, is widely different from the continent of Europe. Of all the English students and architects who annually visit the classic cities of Europe, it is rare to hear of one engaging in actual practice, much less settling in any of them. The number of new and important buildings to be erected is so few in comparison with the amount of local talent, that, although we may now and then hear of an English congregation, in some continental city, getting a design for their church from a London architect, or of an English millionaire employing one of the same fraternity to build a villa on the shores of some Swiss or Italian lake, these instances are so few and exceptional as only to prove the general principle that the continent of Europe, albeit an admirable hunting ground for English engineers, is by no means an attractive field for practice for architects of the same nationality. But it is hard for an English architect of any ability to travel in the United States and not be strongly tempted to settle there. That more have not done so is rather a matter of surprise, possibly to be accounted for by the fearful struggles, political and financial, through which the country has so recently passed, and by the fact that architects are commonly men of quiet and domestic tastes, whose household gods are dear to them, and who, unlike their brethren the engineers, ordinarily prefer modest competence at home to the chances of achieving fame and fortune abroad.

To be sure, a large proportion of the profession in America is composed of men born in the United Kingdom, as is the case there with all other professions and trades. But these men have commonly emigrated while young, and have acquired their profession in America. The number of those who have studied in Europe is comparatively small, and it is to be observed that in most instances they occupy important and leading positions. Of course they are at a slight disadvantage at the outset compared with native Americans, possessed of local knowledge and influence, but this is soon overcome, and they are, or ought to be, possessed of great advantages over the foreigners of other nationalities, French and German for instance, in speaking the same language as prevails in the country of their adoption, and being accustomed to nearly the same laws and social usages. Diversities of this kind, though usually mastered in time by the Germans, seem to present an insurmountable obstacle to the success of our Gallic neighbors in

the practice of architecture in the United States. Architects of other nationalities may be thankful for this, for American taste is so decidedly in favor of everything French, and French ability, I need hardly say, is so strongly marked, that if French architects were only to take kindly to American soil they would soon carry all before them upon it. As things are, however, the field, though wide and open to all nations, is so circumstanced as to invite English-speaking architects more strongly than any others.

These views may seem, at first sight, to be at variance with those expressed in a paper on American practice recently read by me in New York, as it is there stated that architects are neither so much appreciated nor employed in America as in Europe. But this seeming contradiction will be reconciled when the causes are investigated, some of which are dealt with in that paper. I am convinced that the American public only requires to be shown what well-qualified architects really can and ought to do for them, to appreciate and remunerate them correspondingly. But so long as architects there are content, as they are, to neglect the constructive, financial, and executive parts of their profession, and choose to devote themselves almost exclusively to the æsthetic, it is no wonder that so eminently practical a people hold them in slight esteem, and look upon them to a great extent as mere draughtsmen.

With these preliminary remarks I will now proceed to give some account of the condition of the art itself, as shown in the principle buildings, which I will endeavor to describe under their several classes.

Vast as is the territory of the United States, its active life is, I think, more concentrated in cities than in Europe, and it is in them we must look for the best types of American architecture. The smaller country towns and villages can scarcely be said to possess any architecture at all, being often built wholly of wood, in plain box-like forms, or else of brick, used in equally simple forms, and taxing no other resources than those of the local "boss" carpenter or mason. There are but few country mansions on a large scale surrounded with ample demesnes, such as are to be found in Europe, consequent on the absence of a territorial aristocracy. There are, however, in the vicinity of all large cities numerous pretty villas occupied by wealthy merchants and bankers, which bear a close resemblance to the same class of houses in the old country, with some marked peculiarities to be presently noticed. The more common ambition, however, of the American millionaire is to build neither a country mansion nor suburban villa, but to erect for himself a gorgeous town-house on Fifth Avenue, New York, or some of the corresponding streets in other cities. City life is, for various reasons, the most attractive, elegant and fashionable, and hence the town houses, especially of New York, are by far superior to the country or suburban, and compare favorably with those of most European capitals.

Of course, in the wealthy and fashionable quarters, churches of corresponding character must be looked for; religion, although not specially recognized by the State, being quite as fashionable in America as in England, and hence, in these quarters of the chief cities, we find costly churches of nearly every denomination alternating with lines of stately mansions, and as different in their character and cost from the simple wooden-spired boxes to be found in the villages above-mentioned as can well be conceived. In the poorer quarters of the cities the churches are of corresponding character with the houses around, and may be shortly described as being nearly all of what is known as the "Little Bethel" type amongst ourselves.

The unsettled habits of so many of the American people, and the great expense of housekeeping, causing a large and respectable section of the community to reside in hotels, have developed the latter so as to rank amongst the "great institutions of the country," and as examples of architecture they will require special notice.

The vast commercial relations of the great cities have also required that warehouses and shops, or "stores," as they are called, should assume enormous dimensions, and they are more often than with us highly decorative and palatial in their appointments. Banks and insurance offices, also the offices of

the numerous journals, form splendid subjects for architectural treatment, and are commonly carried out in a liberal spirit.

The post-offices, custom-houses, and law courts have nearly all recently undergone a process of reconstruction on a much grander scale than before, chiefly by the United States Government, and, if we except the miserable pittances paid to the architects, no expense seems to be spared to render them worthy of a great nation. The telegraph offices, albeit still in the hands of private companies, have also recently been taken in hand, and some noble buildings are in progress for these purposes. The railway stations, or "depots," as they are called, are rather behind in the race, being as yet generally temporary wooden sheds, and but one really colossal terminus worthy of comparison with those of Europe, has as yet been erected in New York.

The town or city halls, and the State Capitols, in which the legislatures of the various States hold their meetings, have nearly all been found too small and old-fashioned for modern ideas, and some very noble and magnificent new buildings are either in progress or projected for these purposes.

There are large and handsome theatres and opera houses to be found in every great city, which, from their occupying excellent and commanding sites, and the general spaciousness and elegance of their appointments contrast most favorably with ours. The same may be said of the music and lecture halls, which especially abound in Boston and New York.

Public museums and picture galleries are as yet in their infancy, and can scarcely be expected to rival those of Europe for many years to come, but every large city has a respectable public library, the buildings for which are often costly and handsome. There are in New York, Brooklyn and Boston appropriate buildings for the purpose of annual art exhibitions.

Charitable institutions, such as hospitals and asylums, appear to be as well sustained and appointed as any in the world, and some of the buildings for these purposes are very extensive and magnificent. In a country which has set so good an example to our own on the subject of education, it is only to be expected that schools and colleges would abound. Of these buildings, the public schools, commonly erected by the city or state authorities, though often spacious and well appointed, are rather commonplace building than architecture. The colleges as yet seem to suffer from the want of adequate funds. The two well-known universities, Harvard and Yale, have no state endowments, and are dependent on private munificence. Hence, venerable as they are, they have as yet little to show that can be called architecture, and that little is of a very poor class. Trinity College, Hartford, Connecticut, has recently sent over to Mr. Burges for designs for a new college on an immense scale, which have been illustrated in some of the English journals, and the first instalment of which, I understand, is about being contracted for. One of the latest founded universities, Cornell, in the State of New York, has, however, shown its appreciation of our art by the appointment of a professor of architecture (though, singularly enough, a clergyman has been selected for the post), and I believe similar professorships are in contemplation at Harvard and Yale. There is in Boston an excellent scientific school, the Massachusetts Institute of Technology, which has a professorship of architecture attached, to which, however, an able practising member of the profession, Mr. W. R. Ware, has been appointed. I hope these may be hints to the board of our honored University of Dublin to follow the same example, which has also been set by Oxford, Cambridge, and London.

The public cemeteries compare very favorably with ours, not alone in the sites they occupy, but also in regard to the order in which they are maintained and the substantial character of the monuments, in which granite and marble are profusely employed. Notwithstanding the costliness of these, and the excellence of the materials and workmanship to be seen in them, they more often display ignorance and bad taste in design than otherwise, for the very simple reason that the American public has not yet generally learned the propriety of employing architects upon them, but

orders them directly from stone or marble masons.

In materials for building, the United States appear to be particularly favored. Granite of varied color, admirable texture, and almost unlimited dimensions abounds, and is extensively used in public buildings, for which the largest columns can be had in one piece, and some varieties admit of being polished quite equal to the granite of Aberdeen. It is also used for paving the side walks, in which it is not uncommon to see slabs 15 feet by 8 laid down, giving the whole width required without a joint. White marble exists in great profusion near New York and elsewhere, and is largely used, so much indeed as to become nearly as common as bath or Portland stone in England. It is easily worked, and gives a beautiful surface without being polished, of which operation, however, it is also susceptible. The sandstone in general use is the well-known "brown stone," raised in the states of New Jersey and Connecticut, and extensively employed in the house fronts of New York, for which it is well adapted, its rich warm tints producing a very pleasing effect. There are also lighter colored sandstones used, from Ohio and Nova Scotia. I do not remember seeing any specimens of oolitic stone, such as Portland or Bath, but it is no great loss to be without a class of material which, however easy to work, is equally facile at disintegration. Red bricks are made, especially in Philadelphia, much superior to any I have seen in Europe, and white or cream-colored, in some of the western states. Cement is rarely used as an external coating, the species of architecture in which it would be employed at home being commonly rendered either in stamped zinc or cast iron, the use of which, in the fronts of buildings, is very extensive, and, as characteristic of the country, deserves special notice.

In woods the United States are rich. The several varieties of American pine we are accustomed to here are, of course, much used there also, but in addition walnut, butter-nut, chestnut, ash, oak and other hard woods abound, and are nearly the same price as pine, the only difference of cost being in the working, which again is counter-balanced by the saving in painting. Hence, these woods are extensively used, and give a fine effect to the interiors, being commonly wrought and finished by skillful cabinet-makers (mostly German) with great taste. The ironmongery in general use seems much superior to the corresponding articles used in England, the flaps of the hinges being usually silver-plated or otherwise decorated, so as to produce a very fine effect by contrast with the polished hardwood of the doors.

In plumbing and engineering works applied to buildings, I must say the Americans appear considerably ahead of us. The excellence and finish of the baths, lavatories and other sanitary appliances in the principle houses and hotels, is such as to deserve the highest encomium. The same applies to the warming of buildings by steam and hot water, in which great progress has been made during the last few years, consequent on the severity of the climate in winter, which severity, however, now is scarcely to be felt, so completely are the halls and passages, as well as the principal rooms, kept to an even temperature by such appliances. I think in this particular we have much to learn from the Americans. The use of lifting-rooms, or "elevators," is very general in all the large and lofty hotels, warehouses and blocks of offices, and the perfection of their mechanism exceeds anything I have seen elsewhere, and has the effect of causing the uppermost stories in these buildings to be nearly, if not quite, as valuable in letting as the lower. From all which it will be seen that in materials, workmanship and mechanical appliances the Americans are greatly favored; and such resources, used under the direction of able architects, ought to result in the development of as noble a school of architecture as is to be found in the world. That this result has not yet been attained is unfortunately the case, the cause being, as I believe, to a great extent to be found in the unnatural severance between the artistic and practical, which has hitherto prevailed in American practice. Many of the largest and most important structures, built of the most costly materials, displaying great excellence in workmanship and a high degree of perfection in their mechanical appliances, have been erected

without any architect at all; the proprietor preferring to place himself in the hands of a "practical man" rather than of an artistic genius, who, as he believes (and too often with truth), knows nothing of the value of materials and work, and can do little else than "draw plans." Of course such occurrences are not universal, but there are enough of them to stamp a vulgar and commonplace character on American buildings, and sometimes to get American architects discredit in the eyes of foreigners for what they really had nothing to do with.

I need scarcely say, if we except the Aztec ruins in New Mexico and Arizona, that there is very little architecture of historical interest in the United States; but such as there is, is to be found in the older cities on the eastern seaboard, New York, Boston, Philadelphia, and Baltimore, and recalls the time of Queen Anne and "the days when George was king." It is a very close imitation of English works of the same time. The early years of the Republic, and the commencement of the present century, seem to have given rise to a few respectable old-fashioned practitioners in these cities and in the then newly-founded city of Washington; and the setting in of the Greek mania in Europe was attended by a similar rage for Greek temples in all these cities, and some of the principal United States buildings, including the Treasury and Patent Office are among the results; also the Girard College at Philadelphia. These buildings are, I think, neither any better nor worse than the corresponding efforts of the Greek school at home. The enlargement of the United States Capitol, conducted under the direction of Mr. Thomas U. Walter, one of the leading practitioners of the time, displays a departure from the rigid Greek types so much in vogue, and, despite the execution of the dome in cast iron, must be admitted to be a very noble and appropriate pile. It occupies a commanding site, and the dome stands well up from the rest of the building, and is seen not alone from all parts of the city, but from the country for many miles around, ordinarily under a clear sky. Having seen most of the great domed structures of Europe I am not aware that any of them produces, on the whole, so fine an effect. Since the completion of this great work a long pause took place in the United States Government operations, until the advent of Mr. A. B. Mullett as architect to the Treasury. This architect, during the eight years in which he held office, certainly had opportunities which fall to the lot of few. Some thirty or forty great buildings, costing from £100,000 to £1,000,000 sterling each, and sometimes even exceeding the latter figure, have been planned and either wholly or partially carried out under his direction. Many of these are illustrated in the last report issued from his department, and those I have seen are executed in the most solid and substantial manner, ordinarily of granite in large masses. Their architectural character though peculiar to the department, may be taken as one type of what is certainly developing in the United States as a national style, and which may not inaptly be described as American Renaissance. Other examples of it are the new State Capitol for New York, in course of erection at Albany, under the direction of Mr. Fuller, and the new city buildings at Philadelphia, by Mr. McArthur, to be more particularly noticed furthur on.

The older portions of the cities abovementioned are nearly as irregular an crooked as any European city, but these portions (except in Boston) form but a small part of the area, the rest being comparatively new and laid out in rectangular blocks, which, however convenient for building purposes, are very prosy and tiresome in effect. Where the ground happens to be irregular it produces very disagreeable results, and indeed, as regards convenience, is not without its drawbacks, as it frequently entails the necessity of traversing two sides of a right-angled triangle instead of the third. In New York it is seen to the greatest advantage, the great length of the island as compared with its breadth giving facilities for it, and the distinction between streets and avenues being easily remembered, also the mode of numbering the streets, but in Philadelphia it is particularly tiresome. It was a great pity that in laying out these cities diagonal lines were not occasionally introduced, and that more space was not reserved for squares and parks.

Except Boston, which has a very fine open space in its midst, called "the Common," none of the cities have spaces of this kind worth mentioning within their ordinary limits, although they have all recently added noble parks in their outskirts, the so-called Central Park of New York being one of the finest. One acre of park or square in the centre of a city, however, is worth a dozen in the suburbs, and Englishmen may be thankful to monarchical institutions for giving London such magnificent breathing spaces, running up into the heart of the city, as St. James's and the Green Park. Dublin may also take pride in the fact that there are no such noble squares in any of the American cities as Merrion-square and St. Stephen's-green. The city of Washington is very nobly laid out indeed on the French system, and is not amenable to the complaint of prosiness or inconvenience attaching to the rectangular style of planning, but it has never filled up as expected, and it will doubtless be many years before it assumes a character worthy of its importance. Although the residence of the President, Cabinet and foreign ministers, and pretty lively during the session of Congress, it is not as yet fashionable, and has little of that metropolitan character which, despite State and Governmental arrangements, belongs properly to New York. The latter city is the real centre of wealth, power and influence, and is destined at no distant day to be a formidable rival to Paris and London in architectural grandeur. As it is, the Fifth Avenue rather exceeds in magnificence any one street or avenue in Europe, and it is the centre of a district which is no unworthy rival of the best quarters of the European capitals.

The climate of the United States, and especially of New York, is eminently favorable to architectural effect. The total absence of smoke, and the frequency of bright clear days and brilliant sunshine, have a marvellous effect in making even commonplace architecture lookwell. Just as amid the smoke, fogs, and dust of London or Dublin the works of the greatest masters become grimy and dull, so there the doings even of mediocrity appear always to advantage. It must be consolatory for the Americans to reflect, however, that, while the architecture of their cities is decidely susceptible of improvement, no earthly power can change the climate of the British Islands.

What Sir Gilbert Scott calls the "vernacular" architecture of the American cities was, until within the last twenty years, a reflex of that of the British, the same mouldings and other features appearing in corresponding places. Within that time, however, chiefly from the large influx of German skilled artisans, a vast improvement has taken place, and the details and finish of ordinary house work are now very much superior to those of the same class of buildings at home. The work, as already noted, is generally done by cabinetmakers, and much more elegant forms and spacious proportions are given to doors and other internal woodwork than what are usual with us. Wainscoting is largely used, and the newels and balustrades of stairs are treated in a highly artistic manner, contrasting most favorably with the meagre and skinny forms customary here.

To remark in detail on the various classes of buildings already referred to, it may be observed that the suburban villas are largely built of wood, and in the use of this material for such, the Americans have developed another variety of the national style, which, though often used with extravagance and bad taste, is also often practised with success. Verandahs are found to be an essential feature in all these, and often very prettily treated, and many frame houses are to be seen, especially in the environs of Saratoga and Newport, which form as elegant and attractive residences as could be wished for. The Gothic style is coming into pretty extensive use for this class of house, for which it is well suited. Brick and stone villas are not so frequent, and where indulged in, their architecture conforms more to the English type, whether of Gothic or Italian.

The extensive use of wood in middle and lower class dwellings in the suburbs of the great cities has had a good deal to do with the extent and destructiveness of the fires which have recently desolated some of these cities. At Chicago especially, although the central and business portion of the city was solidly built, there was, and still is to a

great extent, an immense surrounding district composed of small wooden houses, in which when once a fire got head it spread with unusual force to other districts. The rebuilding of the city, although conducted in a more solid manner than before, will be no safeguard against similar disasters so long as this immense surrounding inflammable district remains as it is, or is permitted to be rebuilt of the same materials. However, in many of the cities, stringent municipal regulations have been passed forbidding the erection of frame buildings within certain limits—a wise precaution, as though when standing apart, frame houses are not particularly objectionable on the score of their liability to conflagration; the case becomes different when a large number are huddled together.

The town houses, of New York and Brooklyn especially, are distiguished by their completeness and elegance. It can hardly be expected that there would be much variety in their external architecture, which is mostly of the American-Italian type, though here and there Elizabethan or Gothic has been tried. The exteriors are, however, generally quiet and gentlemanly in effect, the details of the steps, balustrades, doors and windows being, I think, much superior to ours. The doorways are almost invariably spacious, handsome and inviting, with an external pair of doors disclosing a recessed porch, paved with marble, having handsome glazed doors within. All the wood work being commonly of walnut with ornamental silver-plated hinges and fastenings, the effect is very good. The plans of the houses are different from ours, and are of two kinds, called the "high stoop" and "English basement" respectively, the latter houses being different from anything used in England. The peculiarities of these two plans will be best understood from an inspection of the drawings of each kind. Of course there are many varieties of these two leading types, the "high stoop" being the favorite, and deservedly so, as it admits of considerable expansion. There are some houses of this class on corner lots perfectly sumptuous in all their details and appointments, for the purchase of which sums approaching to £40,000 or £50,000 have been given. The enormous value of land in the fashionable parts of New York renders it almost impossible to get a lot of sufficient size to build a mansion greatly different from the ordinary plan. That of Mr. A. T. Stewart, at the corner of Thirty-Fourth Street and Fifth Avenue is a notable instance, and is built of white marble, and said to have cost, with the site, about two millions of dollars, or £400,000.

These town houses, being some of the most satisfactory buildings to be seen in New York, are, however, rarely the work of architects. I believe originally architects used to be employed on them, and still whenever a very grand one is wanting, an architect is sent for, but they have developed into their present state of completeness chiefly by a tentative process, one builder copying from another this or that improvement, and so on. An English firm, Messrs. Duggin & Crossman, has been distinguished like the Messrs. Cubitt, in London, by the completeness of the houses they have both planned and built. There are in the upper part of New York some very splendid houses from their hands, worthy of the best parts of Belgravia, and costing each, with their sites upwards of £30,000 of our money.

The churches next require to be noticed, and seem quite as numerous as with us, notwithstanding the absence of any State endowment to religion. Although the Roman Catholic and Protestant Episcopal Churches have a large following, the bulk of the religion of the United States is some form of what we are accustomed to call Dissent or Nonconformity, and this has an important influence on the style of the religious edifices, which are called "churches" irrespective of denomination. The older ones to be found in the eastern cities, above referred to, are generally copies of well-known English churches of Wren's time or thereabouts, but more often reproduced in wood than in any other material. The Puritans who colonized the New England States, however they may have hated episcopacy and all its surroundings, seem to have aspired to make the churches they built in the new world as like those of the Episcopal Church at home as possible. Hence in

Boston, Hartford, New Haven and other eastern cities, any one familiar with the London churches can easily count them from their duplicates all round him. Here is St. Clement Danes, there St. Bride's, here St. Martin's-in-the-Fields, there St. Mary-le-Strand, &c. St. Martin's seems to be a prime favorite, and has not only been frequently reproduced in wood, but sometimes in stone also. There is a pretty fair replica of it in the latter material, which has been recently erected for the Unitarians in one of the best quarters of Boston.

There are a few such reproductions to be seen in New York also; but some of the wealthier Episcopal congregations, following the English fashion, have in later times erected some very substantial and monumental churches, reviving the architectural features of the Perpendicular Gothic period. Trinity Church, New York, by Mr. Upjohn, is the best specimen of this kind; it is so accurately reproduced from one of the best English models, that with its churchyard and surroundings, it looks like a bit of the old country bodily transported across the ocean. There is another Trinity Church in Brooklyn by Mr. Lafever, which closely resembles some of the large parish churches erected in England some thirty years ago. It has galleries in the aisles between the nave pillars. These two churches, albeit much behind the modern efforts of the Gothic Revival in England, are superior to most of the churches of late date built in the United States. A few of these latter, built for the Episcopal communion by well-known New York architects, show some advance as regards detail and finish, but none of them seem to have been erected under such favorable circumstances as the two above mentioned. The basilican plan with Lombardic details has been adopted in one instance with marked success in the Church of St. Bartholomew, New York, by Messrs. Renwick & Sandes.

The Roman Catholic community has also erected some very respectable churches, and the cathedral for that denomination, now in progress on Fifth Avenue, from the designs of the last-named architects, promises to be as fine as any modern European church of the same class. It is being built of white marble, in the Geometric or Decorated style, and the works are being executed in the most thoroughly sound and substantial manner.

The churches built for the Episcopal and Roman Catholic communions are, as might be expected, no way different in plan or arrangement from those erected for the same worship in England; but of late years the striving after novelty in the style has led the architects of some of the new and fashionable Episcopal churches to indulge in heights and depths of sensational or "acrobatic" Gothic that are enough to make the hair of some of our Gothic revivalists stand on end. When the architect is done his work, a mediæval decorator is called in, under whose direction the roof timbers, walls and all other available spaces are set ablaze with color and gilding. Nor are the other or non-Episcopal denominations much disposed to remain behind in striving after architectural effect. Although from the simplicity of their worship, and the importance attached by them to preaching, the plans and arrangements have to be assimilated to those of lecture or music halls, still there is a strong disposition to have (externally, at any rate) naves, aisles, transepts, and a tower or spire. Indeed in some instances this disposition has been so strong as to result in the erection of buildings for Presbyterian worship quite as much in accordance with ecclesiastical precédent as any of those erected by the Episcopalians. There is a very elegant Presbyterian Church of this class in Philadelphia, by Mr. Sims, one of the best pieces of modern Gothic to be seen in that city; and a perfectly sumptuous Dutch Reformed Church on Fifth Avenue, New York, by Mr. Wheeler Smith, which, with some extravagances, displays a good deal of taste and knowledge of Gothic detail, and is executed in the best possible manner.

In general, however, the difficulty of reconciling the conditions referred to has led the architects into all manner of devices and disguises, such as rounding off the angles by studded partitions inside, so that the internal plan and section are often circular or elliptical, while all the external forms are square. About the most notable examples of this kind of treatment are the new church on Fifth

Avenue, New York, for the congregation of the Rev. John Hall (formerly of Dublin) by Mr. Carl Pfeiffer, and the new Church of the Holy Trinity, also in New York, by Mr. Eidlitz. Some of the results achieved in the same manner are positively fearful to the unsophisticated European critic. The problem of providing a spacious auditorium, while maintaining a dignified ecclesiastical character, is one which remains yet to be solved at this side also, but the inducements to attempt its solution are much stronger in America than here. For, as already observed, the bulk of the community there is attached to forms of worship which requires buildings primarily contrived for hearing and seeing, and the sums which are devoted to their erection are such as ought to be sufficient to carry them out in a suitable and dignified manner.

Amongst the forms lately introduced for the plans of such churches is the semicircular or that of the Greek theatre, which has been found very successful for hearing and seeing. Such a plan would admit of very effective treatment in the Classic style, but as that has gone out of fashion, attempts have been made to adapt the Gothic style to it, especially at the Rev. Mr. Talmage's tabernacle at Brooklyn, but the result has been anything but a success. Those who remember seeing Mr. Burges's design for a senate house to one of the universities, will be disposed to admit that even in his hands a semicircular plan proved very intractable with Gothic details. Other and more fearful results have been attained by another architect, who has received somewhat of a reputation, by disguising semicircular plans with heaps of towers, minarettes, colonnades, &c., carried out in galvanized iron, as in the Rev. Mr. Hepworth's new tabernacle in New York.

The internal fittings, being nearly always of hardwood, are much superior to the general run of those in our churches, and a much greater degree of attention is bestowed to the comfort of the congregation than with us. The vestibules, passages and pews are usually carpeted, and the warming and ventilation carefully attended to. On the whole, it must be admitted that the American churches are much more comfortable to worship in than our own.

The American hotels form, as observed, a notable "institution" of the country. Built not alone for strangers, but for residents, who board in them to an extent unknown with us, they are usually of colossal dimensions, and should form noble subjects for architectural treatment, though it is to be regretted that they are just as often built without architects as with them. In the large cities the ground floors fronting the streets are ordinarily occupied by shops (or "stores," as they are called), to each of which there is an entrance from the central hall of the hotel, so as to enable the guests to do their shopping without going into the street. The entrance-halls and corridors are unusually spacious, and form a sort of general lounge or exchange, as much frequented by outsiders as by those who may be staying in the house. Off these are billiard, smoking, reading and writing rooms, a telegraph and post office, and office for the sale of theatre and railway tickets, a gorgeous bar for the sale of liquors, newspaper, book and cigar stands; a barber's shop is an invariable adjunct, with bath-rooms and lavatories attached. To secure privacy to the fair sex, a separate entrance for ladies is almost always provided, through which they can reach the most private parts of the house without passing through the Babel of loungers and smokers which ordinarily prevails in the main hall. These private rooms, including dining and drawing rooms, are laid out on a most spacious scale, as also are the various suites of private rooms, to which, when on the upper story, access is commonly had by means of elegantly-furnished and appointed "elevators" or lifting rooms. The hotels at the watering places and in the country differ in having spacious verandahs or colonnades surrounding them, and generally a magnificient ball or assembly room is attached. It is clear that, conceived on this scale, no finer architectural subjects could be wished for; and when we note that white marble and other costly materials are extensively used in them, the principle will be still more manifest. The new and colossal ones at Chicago are certainly very grandiose in effect, and

the best architectural talent of the place has been brought to bear on them; but there are others in which such has been the case, and, however spacious and convenient, they are commonly huge masses of ugly building rather than architecture.

The last large new hotel on Fifth Avenue, New York, was planned as well as built by an enterpising "boss" builder (a native of this country), it being the practice of such men sometimes to profess that they "keep an architect" for the purpose, much as Moses and Son used to keep a poet. The building is a large ungainly pile of red bricks about nine or ten stories in height, but has been sumptuously fitted up inside by some of the able German cabinetmakers or upholsterers already referred to, displaying all "the wealth of Ormus or of Ind," and no doubt producing its full effect upon "kings barbaric," such as Kalakua of the Sandwich Islands, who, as well as the late Lord Mayor of Dublin, were amongst the recent distinguished guests.

The warehouses and shops (or "stores, as they are called) in such a commercial community, also assume colossal proportions. In them more particularly the use of cast iron is general, not alone for internal columns, as with us, but also for all external architectural features. Facades eight and ten stories high are executed in it, and with an excellence of finish and accuracy of detail that is seldom seen at this side. There are several large foundries called "Architectural Iron Works," in which the stock of models is very extensive, comprising all the best examples of the Greek and Roman orders to almost any diameter. The facility with which these can be put together to form showy fronts, has had a very decided influence on the street architecture, which exhibits a great tendency to run into columns, and the repetition of the same details through nine or ten stories is very common. Indeed so prevalent have these characteristics become, that even where cast-iron is not used, the influence of the cast-iron school in this direction is felt. This is noticeable in some of the Great United States' buildings already referred to, which, although built of cut granite, exhibit one order with little variation used through all the stories. This must be looked on as a decided element in what may be called the "American Renaissance" style. Other characteristics of it are the extensive adoption of the mansard or pavilion roof, which is not so much a constructive necessity as a matter of taste.

The ordinary covering of American buildings is tin in plates about a foot square soldered together, laid on boarding with very little inclination. In order to make the roof show, at least in front, however, a steep-pitched or curved roof covered with slate is commonly used towards the street. Recent municipal regulations have required that the rafters, &c., of these should be of iron, and cast-iron crestings and ridges of gorgeous patterns are used upon them.

In the application of cast-iron both to the constructive and decorative portions of their buildings, the Americans have displayed much skill and taste, and at first sight it would seem that the extensive use of this material would be an effectual safeguard against fire. This, however, is seldom the case, as although the facades may be of iron, as above described, the floors fitting into them are of wood, and, from its cheapness, the latter material is used much more freely than with us. Of late years brick arched floors on rolled iron joists have become more general, but still wooden floors and staircases are used in most instances, where stone would be employed with us.

Some of the most important warehouses are not built of cast iron, but of marble, forming very imposing piles of building; and in some of the more recent cast-iron ones, where architects have been employed, praise-worthy attempts have been made to adopt architectural forms, which should not be derived from or suggestive of stone, and in some instances with a fair amount of success.

The banks, insurance and newspaper offices may be placed together as forming another class of buildings on which enormous sums are expended, and architects nearly always employed. Some of these are very magnificent, usually of brick, stone or marble, and quite as sumptuous in their internal appointments as the London buildings for the

same purposes, except that the newspaper offices in the old country do not deserve to be mentioned in the comparison, being, as we know, downright mean and contemptible. The Equitable Life Insurance office, by Mr. Gilman; the New York, by Mr. Thomas; also the Connecticut Mutual and Charter Oak, at Hartford, by Messrs. Bryant & Rogers, will compare favorably with any similar buildings in England or Ireland; but we have no newspaper offices worthy of mention besides those of the *Staats Zeitung* and *Tribune* in New York, the works of Messrs. Fernbach & Hunt respectively.

The architecture of the last-named building is different from anything hitherto described, it being of red brick with granite intermixed, and of a style peculiar to the architect, Mr. R. M. Hunt, whose works are distinguished by great originality and beauty of detail. Their characteristics are difficult to describe, and they will be best understood from inspection of the drawings or photographs of his buildings. Modern French, Gothic and Greek elements are to be found in nearly all his designs, and yet most skilfully and tastefully combined, so that his detail is almost always worthy of close examination and study.

The most important of the telegraph companies, the Western Union, has recently completed a magnificent building for its head office in Broadway, New York, ten or twelve stories in height, of granite or red brick, from the designs of Mr. G. B. Post, the details of which are remarkably elegant, the execution throughout solid and substantial, and altogether the effect very fine as a specimen of a more advanced type of American Renaissance than what has been previously alluded to.

The city hall of New York belongs almost to a past age in the brief architectural history of the country, but it is solidly built of white marble, and really looks what it is, an uncommon point of excellence, where the uniformity of the prevalent style makes it often difficult to distinguish the purpose of a building from its external appearance. That of Boston is newer, of French Renaissance type; but Philadelphia is outdoing all rivals in the erection of the magnificent town hall already referred to, a full set of photographs of which, kindly presented to me by the architect, Mr. W. McArthur, lies here for inspection. The contract for the marble work alone of this great building reaches almost one million pounds.

The United States law courts are commonly held in the same buildings as are used for the post offices, which are, as already described, under the direction of the United States' Treasury; but besides these there are local courts in each city, which as yet are but in few instances worthy of their importance. The city of New York certainly has paid pretty dearly for the unfinished building in which its courts are held, the contracts for which were manipulated by the infamous Tweed Ring so as to make it considerably more than the Houses of Parliament in London. It is a respectable piece of Roman architecture in white marble, and is to have a dome when completed. The court rooms are nearly all square, with few and simple fittings, and are considerably more spacious and lightsome than the corresponding rooms with us.

The state capitols form perhaps the most ambitious class of public buildings, and several new ones on a grand scale are either in progress or projected. That for the State of New York, at Albany (already referred to), by Mr. Fuller, has been illustrated in more than one English journal, and promises to be one of the greatest buildings in the world. It is being carried out in the most solid and substantial manner, and will probably cost almost four millions of pounds. Several others on a smaller scale have been erected in various parts of the Union, generally in the Classic style, and nearly always with domes, suggestive, no doubt, of a family resemblance to the great U. S. capitol at Washington. The State of Connecticut, however, has shown a decided preference for Gothic, and in a recent competition the designs of Mr. Upjohn in that style were selected, and the building is now in course of erection in a thoroughly substantial manner, in granite and white marble, under the direction of Mr. Jas. A. Brown. The contractor, Mr. J. G. Batterson, of Hartford, is distinguished as the proprietor of extensive granite

and marble works, and has contributed largely to the development of the geological resources of the country. The design is noticeable as an attempt to adapt Gothic details to a dome, a feature that some of our leading Gothicists have long desired to reconcile with their favorite style. The cost of this building will probably be about half a million pounds, and another of nearly the same cost is in contemplation for the State of Indiana at Indianapolis.

It will perhaps illustrate the rapidity with which progress is made in the United States when I refer to the complaint* of the late Charles Dickens, that at the time of his first visit no respectable theatre existed in New York, and contrast it with the existing state of things in which that city possesses three or four of first-class dimensions (as large as Covent Garden or La Scala), and a host of minor ones, nearly all of which have greatly the advantage over the London and Dublin theatres in not being huddled away into disreputable quarters, but occupying noble and commodious sites. They are also in general constructed in a more spacious and substantial manner, with wide doorways and passages, and are handsomely furnished and carpeted. The planning is not usually so intricate or scientific, or the decoration so artistic, as in the English or French theatres, but the conditions to be observed are simpler, and the interior effects of some—particularly the academies of music of New York and Philadelphia—are very fine. The external architecture of these two great theatres is simple, being chiefly of brick, but nevertheless is fairly appropriate and expressive; whereas two other theatres, Booth's and the Grand Opera House—the exteriors of which have been executed at enormous expense in granite and marble,—though showing handsome facades, do not appear at all like what they are, and might pass just as well for hotels or banks. In music halls, Boston decidedly carries the palm, having one of the finest I have ever seen, with an organ of stupendous dimensions and power.

The buildings erected for the academies of fine arts, both in New York and Brooklyn, are some of the most favorable specimens of secular Gothic to be seen in these cities, and are the works of Messrs. P. B. Wright and J. C. Cady respectively. These societies, wholly voluntary and self-supporting, have established annual exhibitions of the works of living artists, which are well supplied and attended, and will no doubt grow in importance from year to year. Buildings for State museums, both of the fine arts and natural history, have been commenced in the magnificent Central Park of New York, to receive collections, including that of the Cyprus antiquities, recently purchased by General Cesnola, which are in process of formation. The designs for these buildings are in the hands of an able architect, Mr. Jacob Wray Mould. A very effective building for a public library, rather in the modern French style, is in progress near Central Park from the designs of Mr. Hunt, who was also the architect of the Presbyterian hospital in the same direction, one of the best pieces of secular Gothic to be seen in America.

It is not possible in the limits prescribed for such a paper as this to do more than glance at some of the most prominent of each class of buildings, and I will now proceed to a few remarks on the condition of the profession. It is not by any means as flourishing as the large amount of building doing in the country would lead one to expect. Nevertheless, there are in each large city a number of very successful practitioners, and there is no reason to doubt but that the number will increase according as the American public begins better to understand and appreciate architects and their art. The architects themselves have much to do to diffuse a wider knowledge on the subject, and also, as I have endeavored to show in my previous paper, much to improve in the style of their practice. At present —no matter how lavishly money may be expended in brick, granite, marble, wood or iron, amounting, as will be seen, to four or five times the sums expended on similar buildings in the old country—the American public seems to have little confidence in its architects, and seems disposed to employ and re-

* A similar complaint of more recent date is made by Mr. Anthony Trollope against the railway traveling, which, since the introduction of the Pullman drawing-room and sleeping cars, has become much more comfortable and luxurious in the United States than in the British Isles.

munerate them only on the most limited scale. What stronger instance of this could we have than that of the architect to the United States' Treasury, who, while planning buildings that cost from ten to twenty millions of dollars annually, receives but 4,000 dollars a year himself, or about three times the pay of a bricklayer in the same country? The gentleman already referred to—who filled that office for eight years, and displayed no ordinary ability in the conduct of the vast works entrusted to him—has, it is said in the papers, retired comparatively a poor man, nor has there been any allusion to a pension. Architects in private practice can do much better, of course; but the disposition is very much, as in the case mentioned, to do without them if possible, and even when they are employed, to limit their functions to the supply of the necessary drawings—the superintendence, adjustment of accounts, &c., being placed in other hands. The American public cannot, however, be blamed for this, when the profession itself neglects these two important branches of its duty. It has been credibly stated of a well-known New York architect that, when asked by his client how much the brickwork of a building would cost, remarked that "he had not the least idea, as he really did not know how bricks were sold, whether by the pound or otherwise." No wonder if after this, clients conclude that architects are only fit for drawing pretty pictures, and feel disposed to get rid of the architect once the drawings are prepared, or else place the next monster hotel or warehouse wholly in the hands of some so-called "practical man," as in the cases already alluded to.

The neglect of the financial element in their practice by American architects recently called down on the profession a severe rebuke from the late Governor of the State of New York, who, in his message to the Legislature, drew attention to the fact that State buildings had cost on the average about four times the amount of the architects' estimates. In consequence of this alarming discrepancy he recommended that in future the architects should only be employed to furnish the drawings, and that when once these were obtained a builder should be employed to superintend the work, including the adjustments of estimates, contracts and accounts. This is simply carrying out by the State the same principle which so generally prevails in private practice, and considering architects as mere draughtsmen, unfit to be trusted with anything beyond the limits of their drawing boards. In fact the very word is misunderstood, and whenever a member of the craft wishes to let the public know that he is anything more than a draughtsman, he has to advertise himself as "architect and superintendent of works," as if the former did not necessarily imply the latter.

Among the most obvious wants in America is a weekly journal devoted to the interests of the architectural and building public. In a country where journalism in all other departments is so fully worked, there seems every reason to anticipate success for one such. At present the English building journals circulate largely, but they can neither give local news nor be desirable media for trade advertisements. There is a monthly journal called the *American Builder*, very good of its class, but once a month is not often enough either for news or advertisements.

The most respectable members of the profession in the United States have, during some years past, organized an American Institute of Architects, allied in its objects to those of this Institute, and the Royal Institute of British architects, and deserving of the good will and sympathy of all similar societies, and which, it is to be hoped, will tend, sooner or later, to bring the profession to occupy a higher place in public estimation. It is organized on an admirable plan, by which undue preponderance is not given to any one city, but chapters formed in each, holding meetings and attending to local affairs, all meeting annually in a general convention held in one or other of the chief cities by rotation. This institute owes no small degree of its utility to the secretaries, Messrs. A. J. Bloor and Carl Pfeiffer, to whom, and to the Secretary for Foreign Correspondence, Mr. H. A. Sims, the author of the present paper is indebted for many courtesies. He would be glad

to see the British and Irish Institutes maintain the most friendly relations with so worthy a body, and that all may unite in the sanguine hope that whatever of excellence there is to be found in the past or present of American architecture, is as nothing to what will be realized in its future.

THE IMPROVEMENT OF THE MISSISSIPPI—REPORT OF THE COMMISSION OF ENGINEERS.

From the "New Orleans Bulletin."

The Board of Engineers convened at Port Eads, La., on the 17th of November, and, after examination of the work and subsequent consultation, adopted on the 20th the following general report, and ordered it to be entered into the minutes of the proceedings:

November 20, 1875.

After having devoted three days to examining the works in progress and in conference with Mr. Eads and his Engineers, the Commission presents the following general summary of its views:

Upon personal examination of the locality and observation of the work which has been performed, the South Pass of the Mississippi is found by the Commission to more than fulfill the expectation of its members in regard to its fitness for furnishing an "open mouth" of ample depth for the largest class of sea-going vessels to the Mississippi River by means of jetties.

In making this statement, reference must be had to the fact that two of the members have never before examined the locality with a view to this particular question, one indeed having never before visited the spot. Of course on all points concerning difficulties of execution of the works recommended, they had had no actual local experimental results, while on the other hand, opinions were rife among many that the local peculiarities of the soil, such as its extreme softness, its eruptive "mud lumps," etc., would effectually thwart efforts to lay upon it substantial and permanent engineering construction.

The members of the Commission had, indeed, satisfied themselves that such opinions were unfounded; but it is satisfactory to be able to state positively, after four months of actual operations, that the work of pile driving, extending from the east land's end to twenty-six feet depth beyond the bar crest, along a line two and a quarter miles in length, covering nearly the whole length of the eastern jetty, and an examination of the texture of the bar and of the shoals on which the works are to rest, furnish the most satisfactory evidence of a bottom material not only adequate to bear all the necessary works, but even to suggest that but for motives of economy (quarries being far distant) the jetties, as at the Sulina, mouth of the Danube, might be made wholly of stone. The Commission, therefore, unhesitatingly announces that the supposed or attributed engineering difficulties of construction of engineering works at the South Pass of the Mississippi as depending on peculiarities of the Mississippi delta are illusory.

In fact the execution of the works is far less difficult than that of several recent successful works of the kind on European shores, known to and examined by the members of the Commission. This facility of execution arises, in a measure, from the fact that the broad, lateral shoals, almost bare at low water, which extend seaward from the land's ends, marginal to the channel, form very good protection to the proposed works and almost reduce them to the grade of mere river works until the outer edge of the bar is reached. The deep water portions, outside the bar of the proposed jetties, are comparatively short. While these portions must have the dimensions and strength of exposed sea works they offer no difficulty not common to other similarly exposed works now existing.

It would seem proper in this connection to say a few words as to the South

Pass itself, in reference to its capabilities to furnish an open mouth to the main stream, and thus form an adequate connection between the sea and the thirty thousand miles of inland navigation, which ramify from the river.

The South Pass is the middle one of three great Passes, into which the river, after having for many hundred miles rolled in a single channel, divides a few miles before it finally discharges its waters into the Gulf of Mexico.

It is but twelve miles long, being the shortest of the Passes. From its point of division, it carries its waters in a channel everywhere five fathoms or more in depth, with a straightness of course and a uniformity of section and depth such as almost to suggest to the voyager that he is navigating a canal of unparalleled dimensions, of a width averaging 700 ft., sufficient for the convenient transit of the largest sea-going ships and of the congeries of vessels which constitute a tow for the powerful tugboats in use. No sharp bend, no shoal, no reef embarrasses its navigation.

At the origin—the head of the Passes—a shoal indeed lies in advance of its entrance. This shoal has, however, a natural depth equal to that over the bar of the Southwest Pass, and the Commission anticipates no serious difficulty in effecting over it the required depth. From this point the adequacy of depth continues unbroken for ten miles till the seaward extremities of the land margins (the natural jetties which thus far maintain it) are reached. Here, released from confinement, the current diffuses itself; the depth diminishes until at two miles further (about) the bar, having but seven feet depth, is reached; beyond which, seaward, depths of 6, 12, 24 and more fathoms are found in quick succession. The specific engineering work which the Government of the United States has committed to Mr. Eads is by the well-known method of Jetties, or otherwise called "parallel piers," to supply artificially throughout this two miles from the land's ends to the outer slope of the bar the confining barriers which shall prolong to the sea the uniformity of section and depth which the natural barriers for the preceding ten miles have secured.

This is not the place to discuss the abstract merits of a well-known method which has elsewhere in reference to its application here, been thoroughly discussed and disposed of, and in which the individual members of the Commission have had each one his own part to take. What has been said in former paragraphs suffices to exhibit the strengthened confidence with which personal examinations of the spot and of the works now in progress has imbued the members of the Commission.

The Commission consider the present an opportune moment to record its opinion. First, that the Physical characteristics of the Delta and Bars of the Mississippi and Danube, are similar in many important respects. And secondly, that owing to the greater sea depth immediately beyond the crest of its bar, to the existence of tide-water, to the apparent greater abrading forces along the Coast, and to the extreme fineness of the sand, of which the Bar is composed, the mouth of the South Pass of the Mississippi is *more* susceptible of successful improvement, notwithstanding the greater turbidity of its fluvial current, than was the Sulina mouth of the Danube, when in 1858, the construction of parallel piers was commenced, which secured to the navigation of that river a depth of 17½ feet in 1861, and of 20½ feet at the present time, or five feet more than the works were originally designed to obtain; and this at the mouth of a river-arm discharging less than one-third of the volume of water discharged by the South Pass.

We now turn to the works actually at this time executed by the grantee, Mr. James B. Eads, under the act of Congress authorizing him to improve the South Pass of the Mississippi River, and we find that they have been laid out and thus far carried on substantially in accordance with the plans submitted to and approved by this Commission at the time of their session in September last.

Considering that only the short period of five months has elapsed since the beginning of operations at the South Pass, we are struck with the amount of work which has been accomplished; and although much that has been done is provisional, to be supplemented by other work, it is all necessary and conducive

o the end in view, which is permanently to confine the flow within the space of one thousand feet between the crests of the jetties.

We find from the records of the pile driving, and from the manner in which the piles have thus far withstood the action of the waves and currents, that the material of the bar is even more solid than we had ventured to anticipate it would be, as we have already remarked. We do not entertain any doubt as to the efficiency and permanency of the jetties when they shall have been completed upon the location and plans heretofore approved by this Commission. If the arrangements made by the contractors, Messrs. James Andrews & Co., for the early delivery of additional large quantities of stone for weighting the mattresses, and for the protection of the jetties against the action of the sea, are successfully executed, we see no reason for doubting the realization of definite and permanent good results at an early date. It is hardly within our province, if it were even in our power, to offer any specific opinion respecting the period when a given depth across the bar may be reliably calculated upon, since so much necessarily depends upon the character of the season, the stage of water in the river, and the vigor with which the work is prosecuted; but judging from the amount and character of the work already accomplished in advance of the date at which Congress required it to begin, we are very favorably impressed, believing that there is a prospect of early and complete success.

The lines of the jetties are now distinctly marked out by the rows of piles extending seaward on the east side beyond the crest of the bar into twenty-six feet of water, and on the west side to about twenty feet depth, indicating the extent and shape of the new entrance.

While it would have been unreasonable to have anticipated at this early period in the progress of this important undertaking even as much as has already been effected, we desire to be careful lest we should ourselves undervalue or cause others to view lightly the difficulties which yet remain to be overcome before the final grand result shall have been attained.

Care should be exercised to strengthen the works already commenced, in order to enable them to resist the gales of winter—and too much haste to call in the river forces, for the execution of deepening, must be avoided. It is much safer while the foundations of the jetties are insufficiently protected by stone, to allow the present escape of water by lateral avenues.

From what has already been said, it will have been clearly enough seen that the Commission did not expect at this early stage in the progress of the work that much scouring effects would have been produced. Such results cannot be expected to exhibit themselves in a very marked manner, until, by the closure of the opening, 600 feet in length at the head of the west jetty, and by the raising of both the parallel piers to the water surface throughout some considerable length, the water shall be confined to its destined channel. From the eastern land's end to near the head of the west jetty, the eastern jetty is now for the most part thus raised, while the west bank itself imperfectly fulfills the function of its parallel pier. Throughout this length—say for 4400 feet—a marked scouring effect has taken place.

At this season of the year, when the river is low, the scouring action of the current is reduced to its minimum. This, while it is the least favorable for the exhibition of results from the jetty works thus far executed, is the most favorable to their safe and rapid construction. It is quite undesirable that any considerable deepening of the bar should occur berore the spring shall find the works in a condition to resist and turn to useful account the flood that may then be expected.

On motion:

Resolved, That a copy of the minutes and of the foregoing resume be furnished to Mr. Eads by the Secretary. Whereupon the Commission adjourned *sine die*.

J. G. Barnard, President.
Charles A. Hartley,
W. Milnor Roberts,
Henry Mitchell,
H. D. Whitcomb.

A true copy from the minutes.

H. D. Whitcomb, Secretary.

TERRA COTTA AND STONE WARE AS APPLIED TO ARCHITECTURE.*

By. Mr. JAMES DOULTON.

From "The Architect."

Of all materials that of clay is perhaps the most useful, and in the present age there is scarcely any trade which is not more or less dependent upon it for help of some sort in its manufactures; but this is pre-eminently so in building, where it becomes not a mere help, but an absolute necessity.

Every class of pottery may be comprised under the term terra cotta, or burnt earth; but there are so many kinds of clay, and such a variety of ways of manipulation, that they need some distinguishing appellations, and hence the terms china, porcelain, earthenware, stoneware, terra cotta, &c., each pointing to a special class of ware. But whatever the nature of the manufacture, the first step is common to all, that of the clay being well kneaded. This is as it were the foundation, which if neglected the superstructure will be useless.

The clay for both terra cotta and stoneware may be the same, but it is the treatment that changes the character. In the one instance we have a comparatively imperishable material, naturally unglazed, but which may be glazed at will; while in the other the much more intense heat shrinks the clay to a greater density, and by the addition of salt it is covered with a vitreous glaze, and is impervious not only against atmospheric agencies, but against the strongest acids. Terra cotta, up to the present time, is the only one of these that has been used in architecture, and of this we will treat first.

The kneading of the clay, of which I have already spoken as the first necessary, was originally trodden by men, but now it is pugged through mills; though there are still factories where the primitive system is in use. The clay itself being mixed with other necessary ingredients according to its nature, in a dry state is lifted into the pug mills, where water is added, and by the regular adjustment of its supply the same shrinkage may always be depended upon; the shrinkage being caused by the evaporation of the water used in the manufacture, consequently the less water the less shrinkage. In the course of pugging there is a chance of air getting confined in portions of the clay, which if allowed to remain would be sure to cause destruction while passing through the kiln. To avoid this the clay must be wedged, which is done by continually cutting a lump with wire and striking the pieces violently against each other. The clay being thus prepared, is pressed into the mould, which has been previously made from the model in the usual way. These moulds are of plaster. The process of filling them needs care, for if carelessly done there is a liability of air being incorporated in the body, and the same results as already mentioned would of course follow.

In pressing the clay into the moulds, it should be as nearly as possible even in thickness throughout. Again, the presser introduces into his work, when it consists of large pieces, a series of strutts; this keeps it well together when in a wet state, and at the same time adds considerably to its strength when burnt. The strength may also be increased by thickening the walls. This of course applies to all repetitive work; but when one or even two of a pattern are required, the artist's original production may be burnt.

Of course there are risks in this, from the many accidents to which it is liable in its various stages, and if a piece thus made and burnt be destroyed, the skilled labor or the art work has to be done again; but in properly conducted factories these risks are reduced to a minimum. Many carefully modeled works have been destroyed in the burning from the want of knowledge in this department. In statues, especially, there are so many thicknesses, that without great care and this knowledge distortion is

* From a paper read before the Liverpool Architectural and Archæological Society.

certain. I have known figures made that were solid throughout, and to ensure success in burning had to be dismembered, the clay thinned, and then all reinstated. The most critical time for terra cotta is after it has left the finisher's hands and is drying; this process must have time, it being essential that the moisture should be evaporated as evenly as possible. Should it dry in one place before another it is sure to warp and crack, and no after labor bestowed upon it will ever restore it. Thus it will be seen how many difficulties have to be overcome in the manufacture, and I have thought it necessary to dwell on them in order that the peculiarities of the material may be the better understood, and disappointment avoided by architects desirous of using it.

An eminent architect of the present day calls terra cotta "the highest development of brick," and rightly so, for though it is oftentimes effectively used in stone buildings, its legitimate place seems with brickwork. There are a few examples scattered about in our country, but our architects never seem to have made any but the scantiest use of this material. Wedgewood himself strove to overcome this prejudice, but without success.

For abundance of examples we must therefore look to other countries, where its advantages have been understood and made use of, such as Pomerania and other places in Northern Germany, as also Lombardy. These countries form vast plains, where stone is not found, but where clay is more readily obtainable. Stone could only be procured at great cost; clay, the material at hand, accordingly came largely into use, and architects studying its peculiarities designed accordingly.

The advantages in the use of terra cotta are many, and though it has been known for ages past, has been sadly neglected in these latter times. But while it has many advantages, it is but fair to state that it has also disadvantages; and I will endeavor to lay both before you, leaving the matter for your judgment, as being far more competent in such matters than myself.

The first things to be studied appear to me to be durability and strength, and here terra cotta compares most favorably, especially in the former. Its superiority is the more noticeable in the present age, the formation of cities, towns, &c., causing deleterious elements to mingle with the atmosphere.

The increased consumption of coal, together with the subtle and destructive nature of the vapors given out by factories, require that our buildings to be permanent should be composed of as nearly as possible imperishable materials. Stone, it is very certain, does not supply this desideratum. It was only a short time since that I heard of a building in London of Bath stone, just erected, needing renewal in parts almost before the scaffolding was removed. A portion of the cornice and ballustrade from the church at the top of Langham Place, built about fifty years, fell a short time since with almost fatal results, and has been renewed in the old material, and not in terra cotta, on account of the contrast between that and the soot-stained stone. In the gardens of Buckingam Palace are some vases, sharp and sound, while the stone pedestals on which they stand are fast decaying. There are many ornaments in the Palace front of terra cotta which show not the slightest signs of decay, while it has been found necessary to paint the stone to preserve it. There are other stones more durable than Bath, but they are more expensive. Bath stone itself attains considerable age sometimes, but the present state of our Parliament Houses, where, doubtless, every care was used in the choice of the stone, proves how uncertain it is; whereas the selection of good terra cotta is such an easy matter that any ordinary workman need never err therein. In London many instances may be found of the durability of terra cotta and the untrustworthiness of stone; in fact, nothing seems able to withstand the London climate so well as terra cotta. Granite, indeed, is enduring, but its costliness will always prevent its general use. The bronze lions at Trafalgar Square are already showing many weak points: the panels have done so long since. At a mansion in Bedfordshire, far from any town, I saw, a few years ago, terrace after terrace of Bath Stone in a most deplorable condition, the ballusters being worn in some

places to shreds, while the capping and base, were not entirely gone, had become mere shapeless lines. This would show that the smoke of towns and the vapors of factories are not always answerable for such destruction.

The church in Euston Square, London, has a quantity of terra cotta about it, in a good state of preservation; and, to come nearer home, the figure of Britannia in this city, on the Town Hall, is a specimem of Lambeth manufacture we have no occasion to be ashamed of. Hampton Court Palace possesses some good examples of red; and in the time of the Tudors were erected many mansions in which terra cotta was used, which remains good to this day. Tracing farther back still, we come to those specimens I have already alluded to in Pomerania, Lombardy, &c., some of which were erected in the tenth, twelfth, thirteenth and fourteenth centuries, while the San Pietro in Ciel d' Oro, at Pavia, is attributed to the early part of the seventh century. But a visit to the British Museum will surely convince the most skeptical. Here may be seen slabs of burnt clay which date not tens, nor hundreds, but thousands of years back, covered with delicate writings, showing as clearly as the first day they left the operators' hands. To these slabs we are indebted for almost all we know of prehistoric times. The wonderful discoveries in the present day by Mr. Smith, whose perseverance has been of late so richly rewarded, is but another instance of what I have asserted.

There is no doubt, however, that a material calling itself terra cotta has been used of such an inferior character as to disintegrate immediately on exposure, and many, knowing only the spurious, have been prejudiced against the genuine. Such terra cotta has been improperly fired, there not having been sufficient heat to produce the chemical change which gives to it its indestructible character. The slightest knowledge of the matter would prevent the use of any but good terra cotta, since such may be readily ascertained. Well burnt, enduring terra cotta should ring under a blow, and when sharply struck with a piece of iron show only a black mark as of a pencil, and at the same time emit a spark. These tests are very simple, and as sure as they are simple. I cannot do better in concluding this part of my subject than quote from the works of the late Sir Charles Lyell, who, in his *Antiquity of Man*, says: "In the vast changes this planet has undergone few things remain to mark the Arts of its earliest inhabitants. Flints, spear heads, arrow heads, fragments of iron, of bronze and of pottery are almost all that remain. Of the latter burnt bricks, jars, vases, the human figures in burnt clay are found in the remains of submerged towns, in the channels of the Nile and in Upper Egypt, in the Mexican buried ruins of America and elsewhere, as the enduring types of civilization of peoples and races, whose names even are not known in the pages of history. Granite disintegrates and crumbles into particles of mica, quartz and felspar, marble soon moulders into dust of carbonate of lime, but hard burnt clay endures for ever in the ancient landmark of mankind."

And now let me state a few statistics respecting the strength of terra cotta, and in this it is quite able to hold its own.

Generally speaking terra cotta pieces may be so formed as to resist any ordinary strain, but when extra strength is needed, it is obtained not only by thickening the walls, but by filling the blocks with concrete formed of hard rubbish and Roman cement In resorting to this plan, care should be taken not to use too much cement, nor any, indeed, of a class liable to swell, as in this case the work may crack from the bursting power within. We once supplied some cornice, and advised the clerk of the works how to act should he fill it, and in this case it was not needed for strength, but only to prevent the chance of water soaking in through imperfect joints and being retained. Many pieces, notwithstanding, were filled with neat Portland, of course with disastrous effect, and I had much difficulty in satisfying those concerned with whom the fault lay.

In the year 1868, Mr. Charles Barry, the architect of one of the finest examples of modern terra cotta (I allude to Dulwich College), directed Mr. Blashfield to undertake a series of tests to ascertain the strength of terra cotta in comparison with other materials.

This was done with the following results:

	Tons.
A 12″ cube of Portland stood a crushing strain of	283
The same of Bath	88
The same of terra cotta	442
A good hard stock brick, 9″×4½×3″	17
A piece of terra cotta, same size, almost solid	125

Tests were also made to show the value of filling hollow terra cotta:

	Tons.
A block of hollow work bore a strain equal to the foot square of	22
The same filled	45

But these were not crushed until the immense weights of 80 and 163 tons respectively to the square foot were applied.

Weight is another advantage which terra cotta possesses over stone, and which indirectly affects its cost. Being considerably lighter than stone, there is a saving in transport and handling. In stonework carriage is paid on much that is useless. For carved work the rough blocks are lifted into position, and worked off afterwards; the hoisting being troublesome, and not without expense. Terra cotta, on the other hand, is delivered on to the works finished and ready for fixing, and, being hollow, is of course more easily managed, and where filling is required, it is done on the works.

This decrease of weight has likewise another advantage in diminishing that of the superstructure of a building:

	lbs.
Portland stone weighs per ft. cube.	158
Ancaster " " " } Bath " " " }	140
Terra cotta, solid " "	100
" hollow " "	56

In the matter of cost, terra cotta again compares favorably, and this question of price is constantly thrusting itself to the fore, and I am sure must be a great nuisance to architects, compelling them often to give up their well thought out ideas. Many a building has been spoilt, and the architect blamed, on account of enforced reductions for economy's sake. In London the price of terra cotta would be on an average 20 per cent. less than Bath, and about 40 per cent. less than Portland. Much of course depends upon repetition. In all work models and moulds must be prepared, but for large quantities such an item is reduced for each piece to a mere bagatelle. This comparative cost is again influenced by the character of the work. Where this is plain, consisting for instance of mouldings only, it approaches nearer to stone, but where modeling and undercutting is necessary the advantages is much more marked.

The proportions I have quoted may at times be altered by local influences. Stone may be close at hand, while terra cotta is only obtainable from a distance. or *vice versa*.

Thus I have mentioned four of the advantages of terra cotta—durability, strength, lightness and cost. These may be supplemented by the power of obtaining colors. This is done by applying the color to the burnt terra cotta, and subjecting it again to the fire, previously coating the piece operated upon with a glaze, which, becoming incoporated with the body, firmly fixes the color beneath it. The only natural colors of the clay from which terra cotta is made are buff and red, all other colors being obtained from the admixture of the above, or from the introduction of coloring matter, or by dipping the terra cotta into a colored slip before burning.

The disadvantages in the use of terra cotta are neither numerous nor insuperable, and may be summed up in the one word "time." Of course there is the difficulty of getting the blocks true, but this is a matter mainly for the manufacturer; at the same time much rests with the architect, in designing his plans suitable to the material.

Objections have been made to terra cotta on the score of the extra time required to get up the necessary plans; one set of drawings for the builder, and another set to the shrinkage scale for the manufacturer. There is no absolute necessity for this. Makers are generally willing to undertake this. The full size drawing being thus all that is necessary, they being responsible under any circumstance for the delivery of the correct sized blocks. There are likewise risks in manufacture; some pieces may be destroyed in the very last stages. To prevent this we oftentimes make a few extra.

One great cause of complaint is the necessity of having the details of the work to be executed in terra cotta ready as soon as, or sooner than even the foundations are begun. In answer to this I will merely quote the words of Mr. Charles Barry.

He says, "Of these (that is the disadvantages) perhaps the most embarrassing is the arrangement necessary to have the terra cotta blocks made and ready on the ground before the rest of the work is begun, in order to work in when wanted as the bricklayers progress. At times this is found impossible, and annoying delays in the general work take place, for which clients will be apt to blame their architect. The lesson of course to be learnt from this is, to carefully mature the design at the outset, instead of contenting ourselves, as we now often do, with a mere sketch of what is intended, with the hope and intention of working in parts as time goes on and the work proceeds. I am not sure that architects ought to object to this, since it must produce decision of thought and precision of detail, which may be an advantage in an educational point of view, and is a serious corrective to indolence of thought in design."

Terra cotta has been objected to on account of its retaining its original color and not being toned down by age. Again I will quote an answer given by one of the profession. That if a design requires age before its beauties become apparent, it surely needs reconsideration. But this objection, I fancy, arose from the fact that some few years back it was considered that terra cotta should be very even in color, presenting the appearance of newly dressed stone; whereas one of its great charms is its irregularity of color, a warm tint prevading its whole surface. White terra cotta can easily be made, but is not desirable; it then becomes in appearance a mere imitation of stone; whereas it possesses its distinctive features, which should never be lost sight of.

In designing for terra cotta buildings the nature of the material should always be remembered. Every block should be kept within reasonable limits, and large pieces only used where absolutely necessary, and unbroken lines as far as possible avoided. Large pieces may be made, but they are liable to warp and become expensive.

There are, of course, many kinds of work more suitable to terra cotta than others, such as terminals, ballusters, capitals, panels, trusses, articles which stand alone. Amongst other things it is made to do quite a new duty. In some parts of London it is used for names of streets. Plates, to show the position of fire plugs, have also been made; but, though much approved, these have not yet been adopted in London—the reason, I believe, is that our Metropolitan Board of Works and the Water Companies find it would be an expensive affair to alter the many thousands of tablets, or even replace those that have become obliterated and useless, so each body shirks its responsibility. Every other material would require renewing at some time, but this is imperishable.

But perhaps the most difficult work we ever executed in terra cotta was a Doric portico, where the whole beauty of the design depends upon the straight lines, both horizontal and perpendicular, no break being allowed in the columns, which were about 7′0″ high. The only noticeable defect, however, was in the arch, where I expected none. The foundations were made a trifle too small, not more than 1½″, and the arches being thus a little too large, a true semi was not obtained, and though the key-stone divided the blocks, the error was noticeable to a critical eye.

Stoneware, the subject we have next to treat upon, is a new adaptation of an old material, but, though it cannot boast the antiquity of terra cotta, dates back to a very remote period. It is thought by some that the slight glaze or smear on the Etruscan vases is due to the action of salt. Certain it is that in the excavations made in England several articles have been discovered salt glazed and of Roman origin.

The revival of this art, after many failures, is now being attempted with every prospect of success, and it is only a laudable pride to say that it is without doubt due to the spirit with which the work has been carried out at Lambeth, and the popularity with which it has been regarded. Although the Rhine pottery may have suggested the Doulton ware, the one is by no means a copy

of the other. The former is confined to a delicate blue body, with ornaments of deeper blue or purple, and only in the shape of mugs and jugs. The latter has a far greater range, both as regards colors and shapes.

The old system of salt glazing was like that now used in the Staffordshire potteries for obtaining the flown ware. The articles were placed in close seggars, and with them some salt and litharge, the fumes of which, given off when heated, coated the ware, but only slightly. The present method, and that pursued with the Rhine ware, is at a certain heat to throw salt into the fires, which becoming decomposed, one portion, the chlorine, escapes as vapor, while the other, the soda, meeting the white hot ware, incorporates itself with it, forming a glaze of such a delicate nature as not to obliterate the finest mark ; it is this that makes it so useful in an art point of view. A rich effect is produced by sealing on flowers and dots, each one of which is put on separately by hand, while a wider range of color in the body of the ware is produced by various admixtures of clay, and by what is termed slipping,

The manufacture of these stoneware vases, pots, &c., for domestic purposes has now been carried on for the last four or five years with ever increasing success, and the fertility of design which our artists have displayed is surprising, there being no two alike. And you will be the better able to understand this when I tell you that some of the artists have designed and executed upwards of 8,000 pieces, each one varying from the other. One of the charms of this ware is that the ornament is designed and executed by one and the same person, thus the true spirit of the artist is never absent.

Amongst the many fields to which this class of ware seems to adapt itself is that of architecture. The failure of polished surfaces of the hardest material to retain their brilliancy in external decoration, especially in large towns, at once suggests its use as a substitute for polished granite and marbles ; with this end in view we have made some bosses, ballusters, tiles, &c.

The various colors available must make this ware valuable to those who need variety of tint. These are rich brown, of several depths and clearness, blues of various intensities and opacity, blue green and clear deep green, pink, yellowish brown and clear gray. It is scarcely necessary to speak of the strength of stoneware, beyond saying that it is stronger than terra cotta, and more than able to bear any strain that would be possible to put upon it.

From the nature of this material, it may be easily understood that its cost would be more than terra cotta ; but if compared with the cost of the materials for which it would be a substitute, such as polished marble or granite, it would be far less.

Thus I have endeavored to lay before you the merits and to some extent the demerits of these two materials, terra cotta and stoneware. The former may be considered to have established itself thoroughly as a building material, its daily increasing use being a sure criterion ; but with the latter it is different, and its place in the future as a means of external or internal decoration depends much upon the favor or otherwise with which the architectural profession regard it. The manufacturing difficulties have been overcome, and a beautiful decorative material been produced ; but what its future will be, remains with those whose duty it is to embellish our land with architectural structures, and in some measure to educate the tastes of those with whom they come in contact.

The new Victoria Dock at Dundee was opened with great ceremony, in presence of about 30,000 spectators, by the Earl of Strathmore. The dock, which is nearly opposite the North British Railway Station, covers an area of 10¾ acres. The north wall is 1340 ft. in length, the south wall 950 ft., and the west wall 410 ft., their depth being 31 ft. 6 in. The entrance dock, which communicates with the Camperdown Dock, is 320 ft. long, 60 ft. broad, and 28 ft. deep, and the depth of water in the dock at ordinary neap tides will be 18 ft. 6 in., and at spring tides 23 ft. The total cost of the works is £170,000, and they have been executed by Messrs. A. & K. Macdonald, contractors, Glasgow, in accordance with the plans of Mr. David Cunningham, engineer to the Harbor Trust.

SAGEBIEN'S WATER WHEEL.

From the "Universal Review of Mining."

THE time is not far distant when one class of motors only will have to be considered; when there will be but one theory applicable to motors of all kinds; when this fact is recognized, viz., that there is only one power—if, indeed, there is one—attraction, that it manifests itself among invisible molecules or among visible bodies; or rather that everything is in motion, and that this motion is continually transforming itself and transporting itself according to one single law, although susceptible of an infinity of applications. For a long time past, those who have had to design water-wheels have done so, keeping in mind only the endeavor to discover what speed it was which would give the maximum *useful power*. On the other hand, steam engines have been designed from an entirely different point of view; the endeavor was to find out what should be the cycle of the evolutions of heat, in order to obtain the greatest *motive power* possible with a given expenditure of heat. Pambour was the first to introduce the element of speed into calculations relating to the steam engine; that was a long while ago, but has he been followed in this direction? We consider that the time is come to leave the beaten tracks and fill up the gaps which exist in the theory of motors; to investigate the nature of the complete cycle (*cycle parfait*) giving the maximum of *motive power* in water-wheels as well as in heat engines, and the speed producing the maximum of *useful power* by means of a given motive power as well in water-wheels as in heat motors. But the laws of the maximum of motive power, as well as those of the maximum of useful power, will be the same for all engines. When this is done we shall be in a position to say that the theory of engines is decided, and this is what no one would dare to do at the present time. Indications have, however, been given which leave no doubt about what has just been advanced.

In fact it is well known that, in every engine with a reciprocating motion, there is a speed which gives the maximum of useful power. The relation which allows of this speed being estimated depends partly on the conditions of each particular case, but also on fixed general laws, which we have already laid down in this part of the *Review*. We have also pointed out, in our remarks on the experiment made by M. Lhoest, of Maestricht, that the transmission of power was effected by the same process, that the transmission of motion was attributable to that which we call gravity or to that which we call heat. In order to deprive a body in motion (visible or molecular) of all the *vis viva* of which it is capable within given limits of travel, it is necessary to oppose to it at each instant a resistance equal to its tendency to move, and thus encountering it at the commencement of the travel with a certain speed, to abandon it at the end of the travel with the same speed. Whether molecular or calorific phenomena are in question, this law is expressed by saying that the body which transmits molecular force (heat) from a cold to a hot body, through the intermediary action of an engine, should never be in contact with bodies which have any other temperature than itself. But if, on the other hand, the phenomena produced by visible bodies, such as the vertical motion of a quantity of water, be in question, the same law is expressed in other terms; it is necessary that the resistance to the fall of the water be constantly equal to its tendency to fall, that is to say, to its weight. The conditions are the same, only they are expressed in two different ways. Whence the theory respecting water-wheels, and that of caloric engines have the same laws, or in other words, there is a *single theory as to the means of utilizing natural motions by the intermediary action of engines.*

Two men have brought to a practical result the knowledge which they possessed of this theory: Siemens, of whom we have just spoken, by the invention of his heat motor; and Sagebien, of whom we shall now proceed to speak, by that of his water-wheel. Ths first,

however, has only made his *début*, and has not yet produced a commercially practical engine, while the Sagebien motor, which we shall now describe, is brought to perfection, and has for some time past achieved practical results.

So as not to leave our readers under the disagreeable impression that we have spoken in exaggerated terms, let us hasten to say that the trials made on several of the Sagebien wheels have given proofs that their useful power, measured with the dynamometer, has often attained, and even exceeded, 90 per cent.* The names of those concerned in the trials vouch for the exactitude of the figures.*

On 25th December, 1861, Messrs. Tresca, Faure, Alcan, Delaye, Quinquet, Laforet, Lucas, and other competent practical men, took in hand very careful trials connected with the water-wheel erected by Sagebien and M. Sement, proprietor of a spinning-mill at Serquigny (Eure, France). With the ordinary method of gauging, and the co-efficient of contraction usually made use of, without mistrust, for water-wheels and turbines, the useful effect of the wheel was found to be 103.25 per cent., a result which was evidently incorrect. Sagebien pointed out that, if it were gauged by the method he applied to his wheel, which is a certain one, and which we will describe below, the reasonable useful effect of 93 per cent. would be arrived at. The conclusion to be drawn is that the useful effect of other water-wheels has been greatly exaggerated, through employing a fraction which is too small as co-efficient of contraction. Let us remark that the dynamometer was applied to a shaft mading 71 revolutions per minute, while the wheel only made about one and a-half revolution. There was then between the wheel and this shaft, a train of three geared wheels. M. Guy, principle of the *Ecole d' Arts et Métiers*, Chalons, proved, in the course of various trials, in 1863, a useful effect of 92, and even 95 per cent. He remarked that if he had adopted 0.64 as co-efficient of contraction, in accordance with the hand-books, the useful effect would have appeared as 102 to 103 per cent.; it followed, therefore, that the proper co-efficient was 0.7.

However that may be, M. Tresca, who had to report to the *Société d' Encouragement* upon the trials at Serquigny, found the results so surprising, that he dared not mention them, but commenced a series of trials on other wheels. It was only ten years afterwards that he became convinced, and published his work. We will extract from it the following table of the useful effect of the different water-wheels of Sagebien.

Water wheels of	Useful Effect.	Experimenters.
M. Pécourt, Amiens	0.90	De Marsilly.
Hydraulic Establishment of Amiens	0.94	Lienard.
Traill and Lawson, Beaurain	0.88	
Queste, Bonquerolles	0.85	
Small wheel (ten horse-power) at Chalons	0.93	
Raupp, Houlme	0.88	Slaweski.
Duboc, Cany	0.90	
Cœurderoy, Brionne	0.85	
Depoisses, Brionne	0.85	
Sement, Serquigny	0.93	Tresca, Faure, Alcan.
De Croix, Serquigny	0.82	De Bernay.
Greslé and Toury, Ivry	0.86	Hennezel and Leblanc
Saint Mars, Labruyere	0.85	Julien, Ponion.
Trilbardou (*in water raised for the purpose*)	0.70	Belgrand, Hult.

To these figures we will also add the following:

Forge-Thiry wheel	0.84
Maestricht wheel	0.93 and 0.877.

The first experiments were made by MM. Kraft, Powick, and Sagebien; the second by M.M. Kraft, Devigne. L'hoest, and Sagebien.

The "perfect cycle" of a water-wheel is easy to determine. The water should flow from a higher reservoir, by a channel, to the wheel; then, while fall-

* The Sagebien wheel was not exhibited at Vienna. There were only some imitations—so-called improvements; for it is possible to exceed 90 per cent. of useful power? Will not this figure alone suffice to excuse the mention of this wheel here?

ing, traverse the wheel, and finally deliver itself by a second channel, into a lower reservoir. The section of the inward channel should be calculated so as to deliver the desired volume of water, as also should that of the outward channel for its discharge. If they both have the same inclination, they should also have the same section, so that the speed at which the water flows should remain the same. The maximum of effective power will be obtained, if it be so contrived that in the wheel itself also the speed of the flowing water be the same, notwithstanding the acceleration which the force of gravity will tend to give it ; for opposition offered to the existence of this acceleration is equivalent to the resistance of the wheel being at each instant equal to the power or the weight of the water. This condition is realized by the Sagebien wheel ; whence it happens that its useful effect is so great.

But, to attain this end in a practical manner, what difficulties there are to be overcome ! The water must, in the first place, be admitted without momentum, and without any change in level of the surface, and must then leave it quite spent. It is the surmounting of this difficulty, in fact, which forms the basis of all Sagebien's inventions, as will be seen by the writings of the inventor himself. We cannot do better than reproduce here what he says in a pamphlet published in 1866 :

"This remarkable dynamic produce may be explained, if we consider that, in the system under notice, as will be seen below, there is no loss in fall, on the water flowing into the wheel, on account of the arrangement of the floats, into which the water is conveyed, without experiencing either contraction, alteration of level (*dénivellation*), if we may so call it, or agitation, so that the level of the volume of water which presses on the floats is maintained at the height of fall, in the same way as that which acts on turbines.

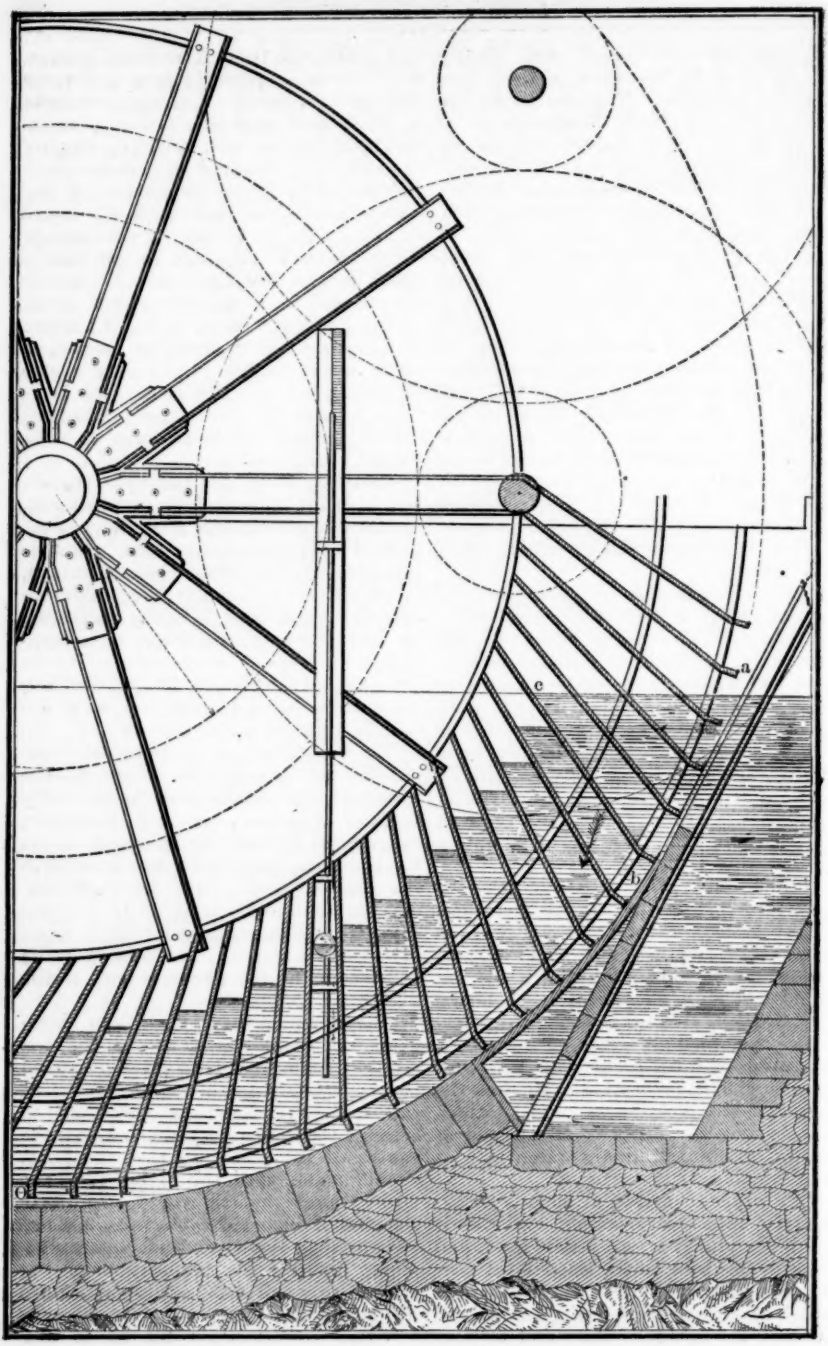
"In order to arrive at such a result, we rely upon this principle, viz., that if a tube be plunged into water, the liquid rises in the tube to the same level as it is immersed, and that the difference which manifests itself, during immersion, between the levels of the water without and within the tube, is so much greater as the tube is plunged into the water with greater speed. Calculations made in accordance with the law of gravitation establish the fact, that, by plunging the tube with a speed of 1 metre (3.28 ft.) per second, the depression of the water in the tube will be 0.051 metre (2 in.) ; that is to say, a pressure of 0.051 metre is required to produce a speed in the flowing water of 1 metre per second ; for speeds of 0.7 metre (2 ft. 3½ in.), 0.6 metre (2 ft.), 0.5 metre (1 ft. 7½ in.), the depressions amount to 0.025 metre (0.984 in.), 0.0183 metre (0.72 in.), and 0.01274 metre (0.5 in.) ; while for a speed of 2 metres (78.742 in.) the depression will be as much as 0.204 metre (8 in.).

"Starting from this principle, the object is to hit upon such an arrangement, as that two consecutive floats may be regarded as a rectangular tube, which is plunged into the inflow channel or race, in as vertical a position as possible, so that the water shall take, by ascension, its level between the floats, in accordance with a speed corresponding to an insignificant depression, instead of doing its work by being poured over, as is the case in ordinary water-wheels.

"It was found to be practically impossible to plunge the floats in the water of the inflow race in a nearly vertical direction ; we have, therefore, endeavored to find the minimum angle for that purpose, which would achieve the desired result, and we have discovered that an angle of 40° to 45° was sufficient, when combined with a speed of 0.5 to 0.6 metre (1 ft, 7½ in. to 2 ft.) per second, at the circumference of the wheel.

"Even under these conditions, however, the employment of the common straight floats, that is to say, those fixed perpendicularly to the circumference of the wheel, rendered it necessary to arrange the inflow very much below the centre of the wheel, so that the floats should make, with the higher race, the desired angle, which would require, in the case of inconsiderable falls, a wheel of enormous diameter. Such an arrangement, limiting the application of our system to small falls, could not afford us entire satisfaction.

"This consideration led us to con-



SAGEBIEN'S WATER WHEEL.

struct, in the case of falls greater than 0.6 metre (2 ft.), a wheel with inverted floats, as shown in the figure, so as to take the water at an angle sufficiently great to avoid any agitation of the water flowing on the floats; and, thanks to this arrangement, we have been enabled to utilize falls of even 4 metres (13 ft.) with a wheel not exceeding 10 metres (about 33 ft.) in diameter.

"The inversion of the floats, which thus enter the water at an angle of about 45°, thoroughly satisfies this condition of maintaining, upon each one of them, the level of the inflow water in the same measure as they dip into it, until the moment when, arrived at the head of the wheel-race, or the sluice, they cease to take the water. The travel of the wheel from *a* to *b*, and that of the water on the float from *b* to *c*, to fill it, being very nearly equal in the same space of time, and the wheel having a speed at the circumference of 0.7 metre (27½ in.) per second, the alteration of level will be, at most, 0.025 metre (about 1 in.) But it will be seen further on, that, in practice, this slight loss becomes even much less.

"Now that the difficulty of taking the water without sensible alteration of level has been overcome, and as the outflow of water takes place without difficulty, it will be possible to increase the thickness of the water-space to an infinite extent, and consequently also the discharge, this latter being in proportion to the height of water in the floats.

"Our practice is generally, however, to keep this height within from 1 to 1.3 metre (3.28 to 4.26 ft.), which represents from 500 to 700 litres (110 to 154 gallons) of discharge per second, for every metre of breadth of wheel, and it is only when we have large volumes of water to discharge, that we arrange a height of water in the floats, which may attain to 2 metres (6½ ft.), in order to obtain a discharge of 1000 to 1200 litres (220 to 264 gallons) per second for every metre of breadth of wheel, with a speed of 0.8 metre (2.62 ft.) at the circumference.

"In order to turn to account the whole height of the fall, it would be necessary to sink the wheel to the level of the water in the floats; but it is often necessary to deviate from this principle when the flow of water is variable. In that case, inasmuch as it is advisable to turn to the greatest possible account the small flow of water during the summer, the height of the wheel is regulated to suit this case, while giving the floats an excess of height sufficient to absorb the water of winter, which may sometimes be double in volume; but then, the water which will occupy this excess of height will not give the same dynamic effect, because at the point where the water leaves the curved portion of the race in its downward movement, a rush will be produced by the portion of water in excess, which corresponds to the loss of a portion of the total fall. We will remark, however, as a set-off, that when there is an abundance of water, there is a power at command in excess of that during the normal state, for which the motor was erected; and, under these circumstances, there is less need to take particular account of the actual dynamic effect, which, moreover, even in this case, has been found to be never less than 80 per cent.

"It will be noticed, in examining the design of the wheel, that each float is terminated at its extreme end by another smaller float, 1 decimetre (nearly 4 in.) in height, the direction of which is towards the centre of the wheel. This arrangement has nothing to do with the useful effect; it is only a simple precaution against accidents which must ensue from the passage of any body offering a resistance to the wheel. It is a fact that, if the floats were to retain the inclination which we give them to the very end, a piece of wood only, passing between the floats and the race, would be sufficient to produce a kind of buttress of such a nature as to cause great damage, while, in the present arrangement, the smaller float can yield to the obstacle and even break, if need be, without any further damage ensuing.

"On seeing the floats thus inverted and sunk so deep, one might be induced to suppose that on leaving the water they would take up a portion with them; but this is by no means the case. The water flowing from the floats into the lower channel, follows the current without any indulation taking place,

and its motion is as unruffled, practically speaking, as that of the water flowing in from the upper channel. It would even seem that this inversion of the floats is favorable to the outflow so long as the speed of a metre per second at the circumference of the wheel be not exceeded. The water clears itself so much the more readily, as it takes from four to six seconds to be completely discharged in its flow from o to D. Let us remark, in addition, that the floats, as they issue from the surface, yield up, at first, but little water at the bottom of the race, at the point o, and that they continue to yield up more and more in proportion as they approach the point, D, where they yield it up altogether. The result is that the motion of the water as it issues from the float is found to be quite uniform with the normal flow along the channels, in which the speed is greater on the surface than at the bottom. If, now, we observe how the water enters the floats from the upper channel, and how it is yielded up into the lower channel, we shall acknowledge that it enters the wheel, keeping, at the same time, very nearly the same flow as that in both channels, since, in this its passage, the different layers of liquid preserve their relative positions, as well in the inflow race as that of the outflow; that is to say that the water taken at the surface of the higher channel, occupying the bottom space in the floats, is delivered on the surface of the lower channel; and also that the water taken at the bottom of the higher channel, which occupies the space between the extremities of the floats, is delivered at the bottom of the lower channel. We dwell upon this circumstance especially, so much the more because it tends to demonstrate the necessity of sinking the wheel as deep as possible, in order to turn to the greatest account all the advantage which this system is capable of affording.

"What we have just said explains the absence of all disturbed motion of the water, not only during its action on the float, but also even on its leaving the wheel; this is very different to what happens in the case of bucket wheels or those with ordinary radial floats, in which the water, independently of the shocks and resilience which take place during its action, has a tendency to strike on the bottom of the race, on leaving the wheel, before proceeding on its proper out-flow course; a circumstance which produces the undulation and resistance which may be observed by all.

"After the remarks we have made above, and the examination of the design of the wheel, it is easy to understand that this appliance is in a position to yield the greatest amount of useful effect that can possibly be obtained from a given fall and volume of water. It also seems to be the only one, hitherto, in which practice has borne out the conclusions of theory.

"One can account, at first sight, for the reason of this, by the mere comparison of our system with that of breast wheels with buckets.

"In fact, we see in our system:—1st, that there is a scarcely sensible alteration of level—not to say no alteration at all—in most cases, we shall presently explain; and that, in all cases, this is independent of the thickness of the water space round the wheel; 2nd, that the pressure of the whole body of the water is brought to bear instantly on the floats.

"In ordinary wheels, a far different state of things prevails. Thus, 1st, an alteration of level is observed, which is much more considerable as the body of water allowed to escape is thicker; and this thickness cannot always be reduced, especially in dealing with a great volume of water; 2nd, it cannot be exactly determined at what point in the wheel the full pressure of water is effective; in fact, inasmuch as the water always comes in contact with the buckets or the floats *in a fall*, the result is that according to the speed of the wheel, the water runs (within a certain limit) after itself, before its weight becomes effective; besides, in consequence of the shocks which it experiences in contact with the buckets or the floats, a portion of the water rebounds, and does not act effectively on the wheel until after it becomes settled, that is to say, at a point lower down.

"If, now, we take into consideration two causes of loss of useful dynamic force, common to both systems, that is to say, the friction on the gudgeons, and the escape of the water between the

the wheel and the sides of the race, the advantage is still on our side as in this case the losses become reduced as much as possible, in consequence of the low speed of the wheel and the slight perimeter of escape, compared with the volume of water given out; while breast wheels and those with buckets, are liable, on the one hand, to a greater loss by the friction of gudgeons (because they revolve at higher speed), and, on the other hand, to a much greater loss through the water escaping; because, as they take the water in as thin a body as possible, and are, consequently, of greater breadth, there is necessarily a greater proportion between the perimeter of escape, and the volume of water given out.

"Lastly, these wheels, as well as those of the Poncelet system, and turbines, both take the water and deliver it with shocks, bubblings, and splashes, which, taking place necessarily at the expense of the motive power, constitute only so much loss to be deducted from the useful dynamic effect, and, notwithstanding their importance, escape being taken into consideration in calculations. Whence it happens that the best applications of these systems have always shown a wide difference between the useful dynamic force really obtained, and that theoretically calculated.

"The same cannot be said of our system. The numerous experiments made with the dynamometer on different wheels have always shown a dynamic produce from 80 to 95 per cent. of the theoretical power."

With regard to the mechanical effect of the Serquigny wheel, M. Tresca says in his report, compiled after so many years of consideration:—"As to the trial made by your commissioners on M. Sement's wheel, for instance, they see no reason to reduce the figure, *which should be well noted*, viz., 93 per cent., as the average dynamic produce of M. Sagebien's wheels. As to the method of gauging devised by Sagebien in order to avoid the adoption of a co-efficient of construction evidently erroneous, we find in the same report:—

"The method of gauging which has best succeeded in the Sagebien wheels consists in the employment of a floating bulb which revolves with the wheel, and which is placed between two float-boards. The tail or rod of this floating bulb works up and down in guides, in the direction of the centre line of the space between the two float boards, and it is sufficiently long for its upper end to be visible at the instant it passes, in a vertical position, before the eyes of the experimenter. It has sufficient play within the guides, while, at the same time, its length of travel is limited, for the figure showing the height of water in the bucket wherein it is placed to be read at each revolution, so that an *absolutely correct estimation* can be obtained of the volume of water contained at a given moment in a given bucket. By multiplying the number thus obtained by the number of buckets, the total volume delivered by the wheel at each revolution will be known, and no error is possible unless, before reaching the position where it is to be gauged, the bucket should have lost a portion of the water which it had previously received.

Sagebien was enabled to calculate the amount of this loss by a hypothetical co-efficient for a certain amount of clearance between the ends of the float-boards and the race. Keeping in mind the large dimensions of the float-boards, the figure for correction is always of little value, and this method of gauging, which is readily applicable to all the wheels of M. Sagebien, offers the incalculable advantage of avoiding the use of the co-efficient of contraction, which other systems admit of, and which, in the case of overfalls from a weir, has always the disadvantage of a tolerably sufficient uncertainty."

M. Tresca also sums up, with great perspicuity, the advantages of the Sagebien wheel:

1.—The Sagebien system is eminently favorable to the utilization of small falls.

2.—Its effective dynamic produce not only attains but exceeds 80 per cent., even when the level of water varies greatly at different seasons, and the wheel must, consequently, be sunk very deep.

3.—This dynamic rusult is entirely ensured when the wheel only makes one and a-half to two revolutions per minute. This last rate of speed should not be exceeded.

4.—Notwithstanding the inconven-

ience of this low speed, the system under notice has, in several cases, afforded a dynamic effect exceeding 80 per cent., measuring the work given out on a shaft making 40 to 60 revolutions per minute.

5.—The breadth of the wheel, with an equal delivery, is much less than that of a breast wheel enclosed in a circular race, because water can be admitted into the wheel at a much greater height, which might, in certain cases, attain and even exceed two metres (about 6½ ft.)

We can add nothing to these words of appreciation, unless it be that M. Sagebien has crowned the system by his last improvement, which consists in the employment of a new method of governing. Up to the present time, all the hydraulic governors known limited their functions to acting on the sluice for regulating the flow of water. Now, it is a well-known fact that it is impossible to shut a sluice with a degree of haste, especially during a sudden acceleration, sufficient to obtain a sensible slackening, due regard being had to safety at the same time. The fact is, that a certain amount of time is necessary for the governor, as well as for a man's hand, to shut the sluice, and after this operation the water which has already flowed into the wheel will necessarily have its effect and prevent the speed from immediately diminishing.

It is for this reason that Sagebien arranges his governor to act at the same time on the regulating value of the wheel, and on a powerful brake bearing directly on the driving shaft so as to store up the excess of speed. This governor has been employed, with the greatest success, at the works of M. Régout, at Maestricht, and also in four works in the province of Liége.

REPORTS OF ENGINEERING SOCIETIES.

AMERICAN SOCIETY OF CIVIL ENGINEERS—REPORT ON THE ORGANIZATION OF A MUTUAL BENEFIT SOCIETY.—A Committee was appointed under the resolution of June 10th, 1875, to "investigate the feasibility and propriety of organizing the Society as a whole, or by voluntary membership, as a Mutual Benefit Society, to aid and benefit the families of deceased members."

The Committee recommends that a voluntary organization be formed within the Society, on the following basis:

1. The organization shall be styled the Civil Engineer's Insurance League. Its place of business shall be at the rooms of the American Society of Civil Engineers, in the city of New York.

2. No persons shall be admitted as members, except Members and Juniors of the American Society of Civil Engineers.

3. The officers of the League shall be a President, a Vice-President and three Directors, who shall choose a Secretary and Treasurer from among their own number. The officers shall be "Resident Members" of the American Society of Civil Engineers, and shall be elected annually on the first Wednesday of November, by a plurality vote of the members of the League present.

4. A statement of the business condition of the League shall be made by the officers on the first of November and first of May in each year.

5. There shall be an entrance fee paid by every person who may become a member. This shall be $5 for persons under 45 years of age, and $10 for persons over 45 years of age.

6. On receiving proof of the death of any member, the Secretary shall at once issue by mail a notification of such death to each member. The member so notified shall thereupon pay to the Treasurer the sum of $5. In default of such payment within 60 days after date of the sending of the notification by the Secretary, the person so defaulting shall forfeit membership in the League and his name shall be stricken from the roll.

7. Upon receiving proof of the death of a member, the Treasurer shall within 3 days thereafter transmit to the heirs or assigns of the deceased the sum of $500, and within 60 days thereafter the additional amount required to make the total sum equal to $5 for each member of the League who has responded to the assessment.

The Committee is of the opinion that the organization of such an association should not be made until 100 persons have signified their intention of joining the same, and to test the feasibility of forming such a League, recommend the passage of the following resolution:

Resolved: That the Secretary be directed to forward to each Member and Junior of the Society a copy of this report, and request a reply in this form, viz.:

I.. .... a (*Member* or *Junior*) of the American Society of Civil Engineers, ...become a member of a Civil Engineers' Insurance League, formed on the basis recommended in the report of the Committee presented November 3d, 1875.

Respectfully submitted,
W. E. WORTHEN, S. R. PROBASCO,
J. J. R. CROES,
Committee.

Among the late papers presented, were the following:—The Efficiency of Steam Vacuum Pumps by J. Foster Flagg; The Verrugas Bridge, by L. L. Chambote.

INSTITUTION OF MECHANICAL ENGINEERS.—The autumn meeting of the above institution was held in Manchester recently, at the Memorial Hall, Albert Square. In the absence of the President, the chair was occupied

by Mr. J. Ramsbottom, one of the past presidents.

After the election of officers for the ensuing year, the secretary of the institution (Mr. W. P. Marshall) read a paper, by Mr. W. Daniel, of Leeds, on mechanical ventilators for mines, in which the author said that in a paper on mining machinery read before the institution sixteen years ago, by the late Mr. T. J. Taylor, the ventilation of mines by furnaces placed at the bottom of upcast shafts, as compared with the mechanical appliances then in use, was for valid reasons considered the best and safest method. But, notwithstanding its admitted simplicity, the rarefaction of the outgoing air by heat to produce the ventilating current had proved troublesome, expensive and dangerous. Under these circumstances it was not surprising that, since the subject of mechanical ventilation was last brought before the institution, six years ago, the adoption of the greatly improved mechanical appliances then described for the ventilation of mines should have been so extensive, and that, in this country there were at present about 250 mechanical ventilators in actual use or in course of construction. In the matter of fuel consumption, the best existing appliances would be about on an equality with furnaces when the latter were employed at a depth of about 700 yards, and the less the depth the greater did the economy of the machine become; but it might certainly be asserted that the furnace ought never to be employed excepting in small mines, where the duration of working and physicial conditions were such as not to justify the additional outlay required for a fan. Most, if not all, of the mechanical ventilators at present in use exhaust from the top of the upcast shaft in the case of pits, or at the end of the return aircourse, where they were employed for day working. The author submitted a statement of the results of experiments on some of the different systems for the mechanical ventilation of mines, and in conclusion called attention to the fact that, in the majority of ventilators now working, low pressures, very little expansion, and consequently wasteful types of engines, were usually employed where, owing to the almost constant work, a more economical engine might be advantageously adopted.

Mr. Charles Cochrane (Stourbridge) read a paper on the "Ultimate capacity of blast-furnaces," in which he said that in the course of a long investigation into the effective working capacity of furnaces, he had been led to conclude that there was an unmistakable source of falling off in the working of blast-furnaces not securely cased in iron, which had hitherto been overlooked, and which in such furnaces was the source of increasing loss the longer a furnace had been in blast.

Mr. L. A. Fletcher also read a paper on the construction, equipment and the setting of the Lancashire boiler.

The reading of the papers was followed by considerable discussion, and some formal business having been transacted the proceedings closed.—*Iron.*

IRON AND STEEL NOTES.

BASACOLT AND ROCHE'S STEEL PROCESS.—This is the conversion into steel of a mixture of pig-iron and ore at a low temperature at the expense of the carbon contained in the pig-iron. The mixture is run in the liquid state into iron crucibles, where it is left to cool, being afterwards exposed to the heat of a cementing furnace brought to a cherry red. A double decomposition then takes place: the oxygenated compounds in the ore give up their oxygen, which combines with an equivalent of the carbon in the pig, and the latter is converted into steel by the excess of carbon and iron from the ore. There is no need for any special appliances, and the method is economical.

IRON IN RUSSIA.—The principal iron mines of Russia are situated in the Grand-Duchy of Finland, in the Oural, the basin of Olonetz in Central Russia, in Poland, and Southern Russia. Ironstone is not only found in mines but in the marshes of Finland and of south-western Russia in Volhynia. The ore is found mixed with organic substances, sand and clay earth. The entire absence of phosphoric acid adds to its excellent quality. Local makers extract by means of little open hearths or mere holes in the ground. The iron foundries in 1873 were 202 in number, blast-furnaces 150. Their product for that year was 336,430 tons of pig, 32,571 tons of castings, 260,959 tons of finished iron, 8188 tons of steel. The Russian founders are now showing great skill in utilizing old rails.

HARD STEEL *versus* SOFT IRON.—Mr. Isaac Reese, of this city, has an invention for cutting bars of hardened steel, and recently Professor B. S. Hedrick read before the American Association for the Advancement of Science, in session at Detroit, an essay on "The Requisite Amount of Simple Friction of Soft Iron against Cold Steel to Melt it." He said the development of heat by friction has been long known. For some time it has also been known that the operations of rubbing and rolling had the effect of changing the molecular structure of iron and steel. These operations will toughen and compact cold iron, and will harden and condense steel. Some time since Mr. Jacob Reese, of Pittsburgh, Pa., had occasion to construct a machine for cutting bars of cold-hardened steel. For this purpose he mounted a disc of about forty-two inches diameter, made of soft wrought iron upon a horizontal axis, so as to be rotated with great velocity. With any moderate speed no cutting was produced. But on giving the disc such a speed of rotation as to cause the periphery of the disc to move a velocity of about 25,060 ft. per minute—nearly five miles—the steel was rapidly cut, especially when the bar to be cut was slowly rotated against the disc. Sparks in a steady stream were thrown off. But on examining the pile of accumulated particles beneath the machine they were found to be welded together in the shape of a long cone, similar to the stalagmites in the lime-stone caves; they were nearly like the spikes of frost as formed in winter on Mount Washing-

ton, and illustrated at the Troy meeting. Real fusion takes place. The steel is melted by the swiftly moving smooth edge of the soft iron disc, but the disc itself is but little heated. The bar of steel on each side of the cut receives but a slight heat, not at all drawing the temper, or oxydizing it. By this process a rolled, polished and hardened steel bar of two or three inches in diameter may be cut in two in a few minutes. The soft metal disc of iron used was about forty-two inches in diameter. The particles fly off in thick jet or stream through which the naked hand may be passed without injury. They glance off without burning the hand, having assumed the condition which causes the spheroidal state of liquids.—*Pittsburgh Leader.*

RAILWAY NOTES.

THE *Levant Herald* says:—"The working company of the Ottoman railways has, we learn, stopped the works which were in progress on the Shumla line, and which, after several years' delay, had at length been begun in October last. If we are rightly informed, the principal cause of this stoppage is the non-payment of the bi-monthly certificates presented by the company to the Government. These certificates having remained unliquidated for more than six months past, the company has, it appears, found it impossible to go on making advances to the Government for the execution of the works, and is now compelled to dismiss its workmen. Under any circumstances this step is to be regretted—the more so since it is always much less easy to take up again works which have been suspended than to carry them out interruptedly. The Shumla line, which according to the existing contract, ought to have been completed at this very time—that is to say, by the 18th of May, 1875—is of peculiar interest to our public, inasmuch as it would have put Constantinople in railway communcation with the rest of Europe, through its junction at one end with the Yamboli line, which is already being worked, and at the other with the railway from Varna to Roustchouk. In a strategical point of view, moreover, it would have been desirable that the stronghold of Shumla should have been connected as soon as possible by rail with the interior of the empire."

ENGINEERING STRUCTURES.

WHILE Mr. James Anthony Froude, says the *Inter-ocean*, has undertaken to turn the current of British emigration from America and Australia to the possessions of her Majesty in South Africa, Captain Sir John Glover has conceived a bold project for the civilization of the same part of the globe. This scheme is the formation of a canal for commercial purposes from the mouth of the river Belta, on the Atlantic, in the neighborhood of Inby and Cape Bajador, opposite the Canary Islands, to the nothern bend of the Niger at Timbuctoo, a distance of 740 miles. Such a highway would open up the African continent to the world, and it is believed that no formidable obstacle opposes the construction of the work, but that the great Desert of Sahara favors it. For 630 miles of the distance there is a large hollow, supposed to be 250ft below the level of the Atlantic ocean, which was probably at one time covered by the sea. The low country is separated from the coast by a broken ridge of about thirty miles, through which the river Belta runs for twenty-five miles, so that all that would be necessary to reach it is to deepen the channel of the river, cut through the ridge, and let the waters of the Atlantic fall into the vast arid basin. In this way a fine sheet of water would be formed, the climate would be improved, the country would become more fertile for pasturage and agriculture, and commerce would be carried into the heart of Africa. It is a fine project, second, says Sir John Glover, only to the Suez Canal; but very much remains to be done before its practicability can be considered certain. Its author, Mr. Donald Mackenzie, proposes to organize an expedition to establish a station at the mouth of the river Belta, in the first instance, and then make a scientific survey of the country. If it could be shown on good independent authority, that the scheme can be executed at a reasonable cost, there is no doubt that the enterprise of England would prove equal to such a work.—*Engineer.*

HYDRAULIC LIFTS ON CANALS.—The trustees of the River Weaver Navigation attended on Wednesday last the formal opening of a hydraulic lift for vessels, which forms a new and most important improvement in canal navigation. The site of this new invention is at Anderton, where the Trent and Mersey Canal, on its way to Runcorn, approaches the river Weaver. There is already a considerable trade passing from the canal to the river at Anderton, proceeding from the iron and pottery districts to the sea at Liverpool; but, as the canal is over 50 feet above the river, the whole of this trade has hitherto been subject to transhipment, which necessarily involves a great expenditure upon labor. The object of the trustees has been to raise the river vessels at one sheer lift up to the level of the canal, and to lower the canal vessels by the same means to the river, thus establishing as complete intercommunication between canal and river as if no difference of level existed. With this view their engineer, Mr. E. Leader Williams, C. E. (now engineer to the Bridgewater Trust), placed himself in communication with Mr. Edwin Clark, C. E., of London, and Mr. J. T. Emmerson, of Stockport and Liverpool, who are respectively the designer and builder of the great hydraulic ship docks of Malta and Bombay; and these gentlemen undertook, in co-operation with Mr. Williams, to fulfil the wishes of the trustees in a successful manner. They have accordingly formed an extension of the canal in two branches towards the river in wrought iron, and adjacent to these, and capable of direct water communication with them, have placed a double lift, which takes the vessels, up and down by means of hydraulic power actuated by steam. The lift consist

of two large wrought iron tanks, or open pontoons, situated side by side, and each of equal section with the canal, and of a length sufficient to receive the longest of the vessels which navigate the canal. One pontoon ascends while the other descends, the time occupied in making the ascent and descent being on an average only about three minutes. Each pontoon is fitted with ends that lift up when connection has to be made with the canal or the river, thus allowing a free passage for the vessels out of or into either. These lifting ends, and the junctions of the pontoons with the iron branches of the canal, are all made perfectly watertight by means of very ingenious arrangements of india-rubber packings, which are brought into operation by the motions of the lift and the pressure of the water. The work has been carried out by Messrs. Emmerson, Murgatroyd & Co., under the inspection of Mr. James Watt Sandemann, C. E., the present engineer of the Weaver Trust. Several vessels were taken up and down with rapidity, and the satisfaction felt with the operation was general and complete. It is considered that this means of direct connection between the canal and the river Weaver will greatly increase the trade and income of the latter. —*Architect.*

ORDNANCE AND NAVAL.

THE COLBERT, which is an armour-clad of first class, was launched a short time since at Brest. This vessel was built from designs by M. Dupuy de Lome, modified by Messrs. Sabattier and d'Amtly, and was laid down in 1869, and thus has occupied nearly 6½ years in construction. Her length is 102 metres, breadth of beam 18 metres, and mean draft 8 metres; she is fitted with engines of 1000-horse power. This vessel is armed with 4 mitrailleuses, 6 guns of 27 centimetres calibre for the central turrets, 2 guns of same calibre for side turrets, 1 gun of 24 centimetres, and 6 of 14 centimetres on main deck. The Colbert and Richelieu, recently built at Toulon, are the only vessels of this type in the French navy. The total cost of this vessel completely equipped is estimatted at 8 million of francs (£320,000).

THE THUNDERER, double turret monitor, has not come out perfectly unscathed from the protracted and severe trials to which her 38-ton guns and the working gear have been subjected. In consequence of the severe concussion of the guns when depressed, some of the T-iron beams which support the superstructure have been loosened from the bolts which secure them to the sides of the ship, while cracks have shown themselves in the welding at the ends. The fissures in no way affect the turrets, which are independent of the superstructure. The injury is wholly due to the explosion of the enormous powder charge sweeping over the deck. At Devonport a short time ago the depressed fire of a turret ship tore open the deck. As the result of his experience on board the Devastation during her passage to Malta, Mr. Barnaby, director of naval construction, has recommended that the Thunderer should be furnished with a patent cable controller, the present arrangement being extremely dangerous to human life on the anchors being let go. The four spocket wheels over which the cables pass will be all on the same shaft, and will be checked either singly or together by the controller, which will be worked by the capstain engine.—*Engineering.*

A GUN PLOUGH.—A prophecy, says an American contemporary, ascribed to both Isaiah and Micah, foretels that the approach of the era of good will upon earth shall be hailed when men "shall beat their swords into plough-shares, and their spears into pruning hooks." We fear that the faith of believers in the speedy advent of this period will receive a shock on reading the account given below of a cunningly devised anti-millennial device. Unmindful of the prophecy referred to, on June 17, 1862, C. M. French and W. H. Faucher obtained letters-patent for a combined plough and gun. The utility of this formidable agricultural implement is expected to assert itself in "border localities subject to savage feuds and guerilla warfare. As a means of defence in repelling surprises and skirmishing attacks on those engaged in a peaceful avocation, it is unrivalled, as it can be immediately brought into action by disengaging the team, and in times of danger may be used in the field, ready charged with its deadly missiles of ball or grape." The stock of the plough is the gun, and the share serves to anchor it firmly in the ground, the handles in the rear being brought into requisition in aiming the gun. At this distance from scenes of "savage feuds" we are, perhaps, not able to appreciate this invention; but that it is an agricultural curiosity we must admit. We may next hear of war-like milk-pails for Amazonian dairy women.

BOOK NOTICES.

CHEMICAL EXAMINATION OF ALCOHOLIC LIQUORS. By ALBERT B. PRESCOTT, M. D. New York: D. Van Nostrand, Price, $1.50.

The objects of this manual, as stated in the preface, are to give in outline the chemistry of alcoholic liquors, including their current impurities and adulterations, in such terms as to be understood by persons having only an ordinary acquaintance with chemical science; and secondly, to furnish directions, as far as possible, for an efficient chemical examination; not more elaborate than is required for commercial, hygienic and legal purposes, and containing all details except such as are to be found in every rudimentary treatise on chemical analysis. The writer, we are happy to find, holds it to be of absolute importance to society that all articles used as foods, medicines or beverages be made subject to strict examination by authority of the law, and that impurities and additions be systematically exposed and suppressed. The author carries out his plan in a very satisfactory manner. Under each alcoholic liquor he describes the normal constituents, and then the fraudulent additions or substitutions.

Thus we are informed that genuine wine (the fermented juice of the grape without any addition) contains:—

(*a*). Alcohol, 7 to 20 per cent. by weight.

(*b*). Non-volatile substances, 3 to 10 per cent., including—

Grape-sugar 0.1 to 3 per cent. (in a few varieties of wine 10, 13, 14 per cent.)

Free fixed acid, equal 0.3 to 0.6 of tartaric.

Tanic acid, 0.08 to 0.20 per cent.

Glycerine, 0.1 to 0.5 (maximum 2.0 per cent.)

Albumen (nitrogen from 0.02 to 0.06 per cent.)

Gum. pectin, fat, wax, color, ash, 0.17 to 0.27 per cent. (Potassic phosphate, fully two-thirds the ash.)

Tartrate of ethyl (decomposed upon evaporation.)

(*c*). Volatile substances, besides alcohol and water.

Ethers.

Fusel oil.

Acetic acid (0.06 to 0.12 per cent.)

We must remark that the author does not use the term "fusel" as a mere synonym for amylic alcohol, but extends it to all those products of fermentation which distil at a temperature higher than the boiling-point of ethylic alcohol. He quotes from Schmidt's "Jahrbucher Gesam. Med.," 1871, B. 149, p. 264, some interesting information on the physiological action of these compounds, which fully confirms the prevalent notion of their insalubrity. Amylic alcohol, it appears, produces poisonous effects, closely resembling those of ethylic alcohol, but of fifteen times greater intensity. Frogs were floated in a 0.002 solution of the alcohol (one part to 500 parts of water), and then in stronger solutions, and the effects of depressed action of the heart, congestion, anæsthesia, and death were timed. Amylic alcohol produced the same effects in the same time as did ethylic alcohol of fifteen times greater concentration or butylic alcohol of three times greater concentration; from which it was inferred that the poisonous action of butylic alcohol is five times more intense than that of ethylic alcohol in the same quantity. Rabuteau also experimented on himself, taking from four to eight grains of amylic alcohol in a glass of wine, and the results confirmed the conclusions given above. On the other hand, Hermann, in his "Alcoholism in Russia," maintains that *delirium tremens* and acute alcoholism are not found more likely to result from the use of cheap spirits with much fusel oil than from the consumption of the purer qualities. We may here state that in Poland and certain parts of eastern Germany, where highly fuseliferous potato-spirit is extensively consumed, the belief in its specially injurious character is common, both among professional and non-professional characters.

Apropos of poisonous beverages, our attention naturally turns to the worst of the class, absinthe. Dr. Prescott describes it as containing 40 to 60 per cent. by volume of alcohol, and several per cent. of essential oils, those of wormwood, cinnamon, cloves, anise, and angelica being chiefly used, and colored green with leaves of spinach and parsley, occasionally also with acetate of copper or with a mixture of indigo and gamboge. Doubtless by an oversight, he makes no allusion to the specifically noxious quality of this liquor as compared with alcohol. We certainly think it essential that the manufacture, importation or sale of this and of any analogous compound should be, on obvious sanitary grounds, totally prohibited.

Returning to wine, we find, among the list of impurities or additions, sugar to increase the alcoholic strength of wines which would otherwise be weak. The author mentions that not more than 20 per cent. of alcohol can be obtained by fermentation. If a greater amount be detected, the wine is sophisticated by the addition of spirits, generally of a low quality. Glycerine is occasionally added to the extent of 1 to 3 per cent., and if of good quality, free from traces of lead, is one of the most pardonable additions.

Calcined Gypsum is sometimes added "to prevent viscous fermentation, to restore ropy wines, to fix color, and to remove water." It is sometimes sprinkled upon the grapes, constituting the sin of plastering. This evil practice has not only been long and widely followed by the manufacturers—we use the term advisedly instead of growers—of sherry, but is finding its way into Australia. The result is that sulphate of potash is formed in the wine to an unnatural extent; its harsh, saline bitterness greatly injuring the flavor, and its well known action upon the heart rendering it hurtful, even dangerous. We should propose that all wines found to contain sulphuric acid in combination that above the normal amount should be at once condemned and run out into the river. Of course a brisk debate would then arise as to the normal quantity, and those chemists who stated the amount correctly would be pronounced "incompetent" by self-constituted judges. It is an important fact that in the juice of the grape magnesian salts predominate, whilst the fruits with which spurious imitations are chiefly got up are richer in calcium compounds. True wine contains malic and tartaric acids, whilst sham wines are often rich in citric and *horribile dictu* in oxalic. The latter prevails when the fermented juice of rhubarb plays a leading part in the manufacture. Cane-sugar is never found in genuine wine, and its presence is, therefore, a mark of fraud. The author very judiciously remarks that "the artificial production of wines is not, like that of brandy, a task which chemical skill can hope to accomplish. Besides the great complexity of the ethers, the solid extractives are requisite. Then the peculiarity—in many cases the commercial value, of an actual wine depends upon certain proportions of the constituents named above, which proportions the chemist cannot fully determine. The ethers of wine elude quantitative analysis. Moreover, there are doubtless substances in wine not identified. It may be perfectly true that a mixture of pure alcohol, water, glucose, bitartrate, and ethers, may be made in such carefully adjusted proportions that it will prob-

ably be capable of producing whatever effect wine would produce upon the system, and indeed may be less objectionable for administration, more agreeable and more saleable than are many grades of actual wine; yet such a mixture is not actual wine, and should not be presented as such."

In treating of malt liquors, the author does not endorse the view that strychnia, if added to beer, would be thrown out of solution by the tannic acid of the hop. The tannin of the hop does not remain beer. "Moreover, the insolubility of the tannate of strychnia in 20,000 parts of water is by no means assured, and with the solvent action of acetic acid, as in beer, is quite improbable." Further, where strychnia is used, the hops will either be greatly reduced in amount or dispensed with altogether.

We may finally characterise this work as a valuable complement to the labors of Mr. Allen, Professor Wanklyn, and others of the much-abused public analysts who are successfully striving to place the chemical examination of food upon a sound and sure basis.—*Quarterly Journal of Science.*

NOUVELLE MECANIQUE INDUSTRIELLE. Par M. LEON POCHET. Paris: Dunod. For sale by D. Van Nostrand.

This work presents in the fullest manner the theory and practical working of the different heat motors, such as steam engines, hot air engines, gas engines and injectors, together with a full discussion of the performances of compressed air motors.

The chapter on injectors is a complete treatise on the subject. Wherever in the work formulas are deduced by the theoretical discussion, practical examples are made to follow in order to illustrate and apply the principle. The work contains 400 pages of text, illustrated by about 80 wood cuts.

THE CHOLERA EPIDEMIC OF 1873 IN THE UNITED STATES.

A—History of the Cholera Epidemic of 1873 in the United States, by Ely McClellan, M. D., Assistant Surgeon U. S. A.

B—History of the travels of Asiatic Cholera, by John C. Peters, M. D., Ass't Surgeon U. S. A., and Ely McClellan, M. D., Ass't Surgeon U. S. A.

C—Bibliography of Cholera, by John S. Billings, M. D., Ass't Surgeon U. S. A. Washington: Government Printing Office.

The above reports were prepared under the direction of the Surgeon General, and are liable to be regarded by the public as possessing no interest except for practising physicians and health officers. The briefest examination however, of either of the first two reports will convince the reader that no one can afford to dismiss with slight inspection, such masterly records of the work of this great destroyer.

Modern medical science teaches lessons of prevention, and a great epidemic is no longer regarded as an unavoidable *visitation*, except by the ignorant and the superstitious.

This greatest of all epidemics, is proven by these reports to be perfectly controllable by human foresight; its march over the world may be absolutely arrested.

The account of the last visit of true cholera is quite voluminous, but the chain of circumstantial evidence, that it was transplanted from Europe and then propagated through neglect of proper precautionary measures, is presented with admirable skill, the details of cases are given with appropriate brevity, and the proof of a common origin of them all is afforded by the collated testimony, and rendered wonderfully clear by numerous maps. It appears that although this epidemic visited seventeen states and territories, New York and the Eastern States were exempt.

But the portion of the work of most absorbing interest, is that relating to the history of the former regular and steady marches of this terrible scourge; its beginning with the great religious pilgrimages in India, and progressing with terrible regularity along the great avenues of trade and travel, until it had encircled the world, the story is told with graphic power.

The map illustrations are quite abundant and of unusual clearness for a public document.

SCIENCE SERIES No. 20. BRIDGE AND TUNNEL CENTRES. By JOHN B. MCMASTER, C. E. New York: D. Van Nostrand. Price, 50cts.

This work has already commended itself to readers of the Magazine, having been recently printed entire. It is believed to be more complete and practical than any other work so accessible to the practical engineer. The preface to the book which was not given with the Magazine articles, is herewith appended:

"It is the purpose of the following essay to present in as brief a manner as the nature of the subject will allow, the rules and principles, the application and observance of which is of really vital importance in the planning and construction of Bridge and Tunnel Centring. It is not offered as a highly elaborated and exhaustive treatise on this branch of engineering, nor is it intended to furnish a variety of designs likely to be useful to the carpenter and bridge-builder; it does not claim to be analytical; it is purely practical.

Very much, therefore, of what, under other circumstances, might most fittingly have been introduced, has been carefully omitted, and nothing set down which does not bear directly on the subject in hand, and had not been verified, time and again, by actual experiment. It will be observed, for instance, that what may be termed the mathematics of the subject finds no place here. There are no mathematical demonstrations, no lengthy discussions of the various formulæ introduced; they are simply set down as expressing established truths, the proof of their correctness in many cases suppressed, and the reader requested to accept them as true. In the form in which this essay first appeared, this was done to save space; in the present form it has been strictly adhered to, because it is believed that those to whom the work will be of the most use, are precisely those who will be content to take as true the formulæ given, caring very little for the steps by which it has been reached.

In connection with the matter of estimating the load on a centre, four methods have been selected, either of which will give results close enough to the absolute truth for all practical purposes. The first, that of M. Couplet, is extremely simple, and if it errs at all, does so on the side of safety. The second or "graphical" is constantly growing in favor, and most deservedly so; the third, that by calculus, disregards friction and gives results greatly in excess of the truth, while the fourth, or trigonometrical, is perhaps the most exact of all, and admits the application of logarithms.

The remarks on the subject of uncentring are believed to be sufficiently extended, though the subject is one of great importance. The principles, however, to be observed in striking centres are quite few and simple, the observance being all that is necessary to secure success. The sand method cannot be too highly commended.

The remarks coming under the head of tunnel centres, have been limited to pointing out the essential difference between the centre proper for bridging, and that suitable for tunnelling, to calling attention to the peculiar variability of the strains, and to the care to be observed in guarding against the accidents so liable to produce injury to the ribs, and to offering a few practical suggestions as to economy. A few designs have also been added as illustrative of the principles laid down, and as affording examples of cheap and durable frames. The patent centre of Mr. Frazer is worthy of some attention."

The illustrations are numerous and excellent.

SCIENCE SERIES No. 21. SAFETY VALVES. By R. H. BUEL. New York: D. Van Nostrand. Price, 50cts.

This is a reprint of the articles recently published in the *Railway Gazette*.

It is quite exhaustive on the subject of safety valves, and what is more to the purpose, the author's rules and formulas are reliable.

Builders, inspectors and owners of steam engines are equally interested with engineers in this subject, and may find in this short treatise a safe instructor and a guide to practice. The author fully explains his views in the following brief preface:

"The writer, in presenting these remarks to engineers, does not pretend to offer much that is original, but has aimed to gather what is valuable from the great mass of material to be found in scientific periodicals and in publications that are not generally accessible. An endeavor has been made to systematize the treatment of the subject, and to give such varied solutions of the problem that arise in proportioning the parts of safety valves as to render them plain to those who have only an elementary education. The importance of having the general principles of safely valves understood by those who are charged with the care of steam machinery cannot well be overestimated. With a safety valve that is in reality all which its name implies, a large proportion of the risks incident to the use of boilers will be avoided; while on the other hand, a safety valve that is only such in name is one of the readiest assistants to a disastrous boiler explosion."

MISCELLANEOUS.

THE annual import of Bath bricks into the United States is about 10,000 boxes, 24 bricks in a box. Formerly they went in bulk; but so many got broken that it was deemed advisable to have them securely packed. These bricks are manufactured from the deposits of the river Parrett, Bridgewater, Somerset, where millions are made annually. Nowhere else is this deposit found, so that Bridgewater supplies the world, and Bath bricks are as well known in America, China and India as in England.

METAL WORK AMONG THE HINDOOS.—For several centuries India has enjoyed the reputation of having produced some of the most tasteful, if not the finest quality of armor; and the manufacture of swords, spears, daggers, warlike weapons, elephant goads, state umbrella handles, chain-armor, and insignia of rank, has given employment to skilled workmen all over the country. As in Europe in olden times, the chief encouragement has come from the princes, nobles, and zemindars, or wealthy land owners, who have usually kept in their employ skilled workmen and their families, who have devoted all their time and talents to the perfecting of some particular branch of industry. It is for this reason, says Dr. Hunter, in the *Art Journal*, that we often see an amount of labor, manipulative skill and taste expended upon single small articles of little intrinsic value, which would not have been produced to meet the requirements of the ordinary market; but where the workmen have been in the employ of some wealthy rajah, upon whose bounty the whole family has been dependent, time and labor were not of so much consequence as manipulative skill and tasteful finish. This principle has been applied to nearly all the best art industries of India, and the result has been that large families have been trained for successive generations to particular industries, which have been carefully retained, fostered, and brought to perfection in particular districts or villages. Caste prejudices have also contributed in no small degree to keep up the practice, which has some good points to recommend it, though there are objections to the system also, the most serious of which has been that an industry has often died out in a village by the death of the rajah who encouraged it, or on the death of the most skilled workmen. The finest coats-of-mail and chain-armor have been produced in Upper India, and the helmets, cuirasses, shields, armlets, and gauntlets, inlaid with gold, are often most tastefully decorated. The localities where these manufactures attained to the greatest perfection were the Punjab, Umritsur, Delhi, Cashmere and Nagpore. Small weapons, as swords, daggers, battle-axes, elephant goads, and insignia of royalty or of wealth or rank, have been made all over India, and the courts of Hyderabad-Tanjore, Vizianagram, Travancore, Poodoocotta, and many others have encouraged these and similar manufactures.—*Builder*.

GAS LIGHT-HOUSE AT WICKLOW HEAD. IRELAND.

(See Page 102.)